ELECTRONIC TECHNICIAN'S MATE 3c

NAVY TRAINING COURSES

NAVPERS 10145

ELECTRONIC TECHNICIAN'S MATE 3c

PREPARED BY

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PREFACE

This book is written as an aid in preparation for promotion to Electronic Technician's Mate 3c. It is one of a series of Navy Training Courses designed to give enlisted men the background information necessary to perform their duties within their rate.

This manual completes the series of training courses to be used by the Striker in his preparation for the rate of Electronic Technician's Mate 3c. The other texts to be used are—BASIC ELECTRICITY, NavPers 10622; USE OF TOOLS, NavPers 10623; USE OF BLUEPRINTS, NavPers 10621; MATHEMATICS, NavPers 10620.

You are required to study and demonstrate a thorough knowledge of the Basic Electricity manual, but you need to study only the sections of the other three manuals that apply to your work.

In addition to the texts listed above, it is recommended that you also study the section of the Training Manual for Electronic Technician's Mate 2c, Volume II, devoted to Navy test equipment. The information you need to gain from this section is limited to that necessary to train you to use the test equipment in the performance of your assigned duties.

A complete set of qualifications is included in the appendix at the back of this book. Before you can qualify for the rate of Electronic Technician's Mate 3c, you must satisfy the requirements of both the practical and examination factors.

As one of the NAVY TRAINING COURSES, this book represents the joint endeavor of the Training Courses Section of the Bureau of Naval Personnel and of those Naval establishments specially cognizant of the technical aspects of radio.

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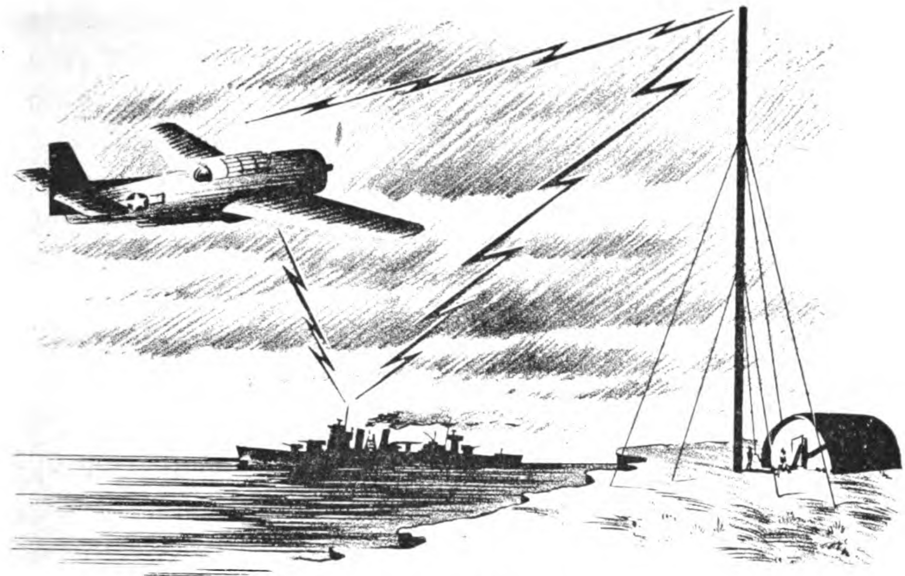


CHAPTER 1

INTRODUCTION TO RADIO

BACKGROUND OF MODERN RADIO

Do you remember the first radio receiver to make its appearance in your home town? Probably not. In 1920, there were fewer radio receivers in American homes than there were ships in the Navy. Yet by 1940—only 20 years later—there were more home receivers in every day use than there were automobiles on the highway.

Radio is such an important part of every American's daily life that we are inclined to think that it has always existed in its present form. Actually, the discovery of its principle dates back to only a few years before 1900.

Marconi is usually credited with the invention of radio. Actually, he was merely the first man to send a message successfully. The principle of wireless communication had been discovered at an earlier date by another European scientist named Hertz.

In the year 1888, Hertz observed that a compass needle placed near a magnet would move each time the magnet was moved. Today that may seem like a simple observation, but he saw something NEW in an OLD principle, and that was—

ENERGY CAN BE TRANSMITTED THROUGH SPACE IN THE FORM OF A MAGNETIC FIELD.

Further experiments revealed that the range of transmission could be increased by alternating current and electromagnet to produce the magnetic field. It was also observed that still greater ranges of transmission were possible when HIGH-FREQUENCY a.c. was used.

From this point on, the development of radio turned toward the finding of a high-frequency a-c generator. Many devices were tried, but most of them failed.

SPARK GAP TRANSMITTERS

One of the first successful transmitters was an ELECTRIC SPARK. When an electric spark jumps from one terminal to another, the full discharge does not leap across the gap once and stay there. It jumps back and forth thousands of times before eventually dying out.

Each time the spark completes one round trip between the gaps, one cycle of a.c. is generated. If the spark jumps back and forth at a rate of 50,000 times a second an a.c. of 50,000-cycle-frequency is generated.

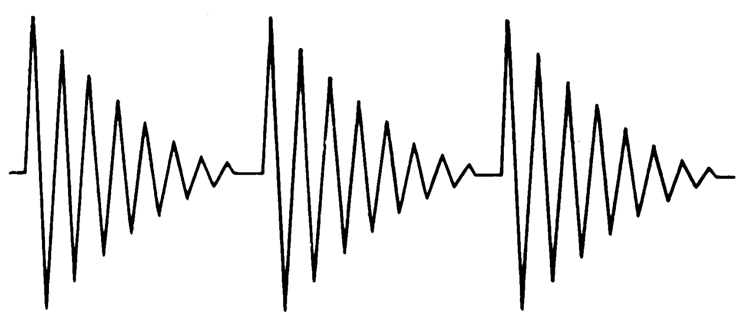


Figure 1.—Damped wave produced by an electric spark.

The oscillations produced by a spark are not uniform. They start strongly, but soon die out, as illustrated in figure 1. When the next spark jumps the gap, they start all over again. The a-c wave produced by a spark is called a DAMPED WAVE.

HIGH-FREQUENCY A-C GENERATOR

Although the electric spark was widely used with early transmitters, it was not completely satisfactory. An ideal transmitter must produce an a.c. that does not die out periodically and must produce a CONTINUOUS and uninterrupted chain of vibrations, as illustrated in figure 2.

The problem of building a useful high-frequency a-c generator was finally solved by the invention of the

VACUUM TUBE. Combined with a few wires, coils, condensers, resistors, and other gadgets, the vacuum tube became the heart of the radio TRANSMITTER.

Remember—regardless of how many wires, vacuum tubes, resistors, and other parts a transmitter may have in its circuit, it is basically a high frequency generator.

ANTENNA REPLACES ELECTROMAGNET

Instead of using an electromagnet to produce the magnetic field, the transmitter uses a single wire or ANTENNA. But the magnetic field is produced in the same way.

The magnetic field produced by the transmitter antenna does not stand still, but travels outward in WAVES from the antenna. Hundreds of miles away, this field will move across the antenna of your receiver and induce an emf in it. In this way, the energy developed by a transmitter travels through space and reappears as an emf in your receiving antenna.

THE JOB OF YOUR RECEIVER

The radio receiver has several tasks to perform. First, it must select the station you wish to listen to. This process, as you know, is called TUNING.

The voltage that is induced in the receiving antenna is weak. The receiver must strengthen—AMPLIFY—the feeble signals until they are strong enough to operate the loudspeaker.

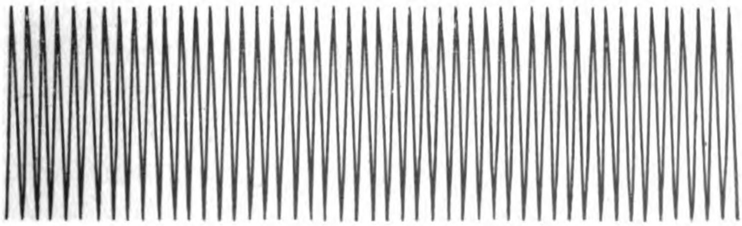


Figure 2.—Continuous wave produced by a transmitter.

If you are receiving a VOICE message, the sound wave and the radio wave were combined at the transmitter into one wave—one package. This process is called MODULATION.

The combined wave must be separated—DEMODULATED—by the receiver. A section of the receiver known as a DETECTOR separates the two waves. The radio portion

is cast aside, and the audio or voice portion is reproduced by the loudspeaker.

Radios that are built to receive CODE messages may be a little different from those designed to receive voice. With code messages, it is the usual practice to send only the RADIO portion of the wave from transmitter to receiver. Since the radio wave is too high in frequency to be heard by human ears, code receivers are equipped with a section that will produce BEAT notes of a frequency that your ear can hear.

WHERE WILL YOU GO FROM HERE?

If at this point, you have grasped the idea that radio communication is achieved by ELECTROMAGNETIC FIELDS traveling from the transmitter to receiver, you are doing all right. The rest of the material is just an outline to introduce you to some of the topics that are to follow.

From now on, the study of radio will be like eating a pie. It is too big to swallow in one gulp, so you break it into pieces and eat it bit by bit. If you persist, and your appetite holds out, you will eventually eat the whole pie.

You have already started to nibble on the crust. The basic electricity you have studied was the first bite. What your next morsel will be depends upon how much you know now. Certainly one of your first will be to become familiar with some of the terms, names, and expressions that are commonly used with radio work. Some of the more important expressions and facts, such as RADIO WAVES, ETHER, RADIO FREQUENCY, and many others are included in the remainder of this chapter.

WHAT ARE RADIO WAVES?

You are familiar with water waves, sound waves, and NAVY WAVES, but what are radio waves?

They are vibrating ELECTROMAGNETIC FIELDS IN THE ETHER. You know much about vibrations and electromagnetic fields, but what's this material called "ether"? Seems to be a little strange.

The ether is an imaginary substance, not to be confused with ether used by doctors. It is present everywhere, even in a vacuum. Like the wind, no one has ever seen the ether but only skeptics doubt its presence.

The ether's reaction to magnetic fields indicates that

it is an ELASTIC substance capable of being pulled or pushed out of shape, but when the force used to produce the distortion is removed, the ether will spring back to its normal position.

HOW A MESSAGE GETS THROUGH

You are well acquainted with the movement of waves in water. When a stone is dropped into a pool, the waves will move outward in all directions until they either die out or reach the edges of the water.

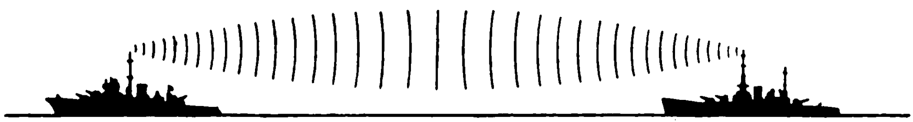


Figure 3.—How radio waves move from the transmitter to the receiver.

Electrons, as they move through a transmitter antenna, cause a disturbance in the ether just like that caused by a pebble tossed into a pond. As illustrated in figure 3, the electromagnetic field caused by the moving electrons will expand outward in all directions and eventually will strike against a receiving antenna and thus deliver the message.

Because it is the electromagnetic radio wave that CARRIES the message to your receiver, radio waves are also called CARRIER WAVES, or many times merely the CARRIER.

There are many forces and outside influences that interfere with the perfect transmission of radio waves from the transmitting antenna to your receiver. Occasionally these outside forces are so strong that the wave is unable to reach the intended receiver, just as a strong cross-wind may prevent the ripples from a stone from reaching the opposite shore. In the last chapter of the training course for Electronic Technician's Mate 2c, Volume I, you will find a discussion of these forces.

RADIO WAVES TRAVEL FAST

Radio waves travel at the speed of light—186,000 land miles or 164,000 nautical miles a second. That speed is

fast enough to circle the earth at the equator about 8½ times in a single second. It may be useful to you in making adjustments on certain tactical equipment to know that radio waves travel at the rate of 328,000,000 yards in a second, or one mile in 6 microseconds—6/1,000,000 second.

SOMETHING ABOUT FREQUENCIES

You have read that the frequency of the a.c. used with radio transmitters is high, but no definite values have been given.

The actual frequencies used extend over a wide range from 30,000 cycles a second at the low end to greater than 30,000,000,000 cycles a second at the top of the band. At the present time, the upper limit is being raised rapidly so that within a year the present high frequencies may be far below the top frequencies actually being used.

Frequencies greater than 30,000 cycles a second are called RADIO frequencies. For the purpose of reference, the full radio frequency band has been divided into seven parts, listed in the following table.

BAND	CYCLES PER SECOND	KILOCYCLES	MEGACYCLES
Very low	Below 30,000	Below 30	....
Low	Up to 300,000	30—300	....
Medium	Up to 3,000,000	300—3,000	0.3—3
High	Up to 30,000,000	....	3—30
Very high	Up to 300,000,000	....	30—300
Ultra-high	Up to 3,000,000,000	....	300—3,000
Super-high	Up to 30,000,000,000	....	3,000—30,000
Microwave	Above 30,000,000,000	....	Above 30,000

Because it is difficult to use numbers that are up in the millions and billions, a system of using larger divisions of KILOCYCLES and MEGACYCLES has been adopted. A kilocycle (kc) is 1,000 cycles, and a megacycle (mc) is 1,000,000 cycles.

If you use the expression "30 kilocycles," you actually mean "30,000 cycles," or if the expression "10 megacycles" is used, it means "10,000,000 cycles."

In addition to the radio frequencies, there is the AUDIO FREQUENCY band. This band includes all vibrations in the frequencies that the human ear is capable of hearing. Most people are unable to hear a sound lower than 20 vibrations a second, or greater than 20,000.

Each of the various frequency bands possesses characteristics that are advantageous for certain types of communication. The bands below 300 are used mostly by shore stations for long-range communications.

The frequencies between 300 and 3,000 kc contain the commercial broadcast bands and some of the long-range medium-wave communication frequencies.

The range of communication systems using frequencies greater than 30 mc is limited to the range of vision. This feature makes it very useful for short range, ship-to-ship communication.

Frequencies greater than 300 Mc are used most frequently with certain types of Navy tactical equipment.

THIS BOOK AND YOUR JOB

You cannot learn by reading alone. Use every opportunity that you have to work with radio equipment. Practice matching up the part, its operation, and its theory. Ask questions and listen to the answers. Sometimes a single word will suggest the solution to a problem that has been troubling you for a long time.

Your ship uses dozens of different electronic devices, including radio transmitters, receivers, radars, and fire-control equipment. It is a part of the requirement for your rate to learn what EACH piece of gear is for, what it will do. Get the chief or some other experienced radio technician to help you out. Ask him to show you how to start and stop the gear and how to make all the operating adjustments. Once you have gained this information, it will be much easier for you to service and maintain the gear in good operating condition.

ELECTRICITY FOR ELECTRONICS TECHNICIANS

Many students find it difficult to apply the basic principles of electricity to the study of radio. That is a natural but unfortunate situation. The following chapters are aimed at providing the information necessary for bridging the gap between the study of general principles of basic electricity, and their SPECIALIZED application to radio and electronics.

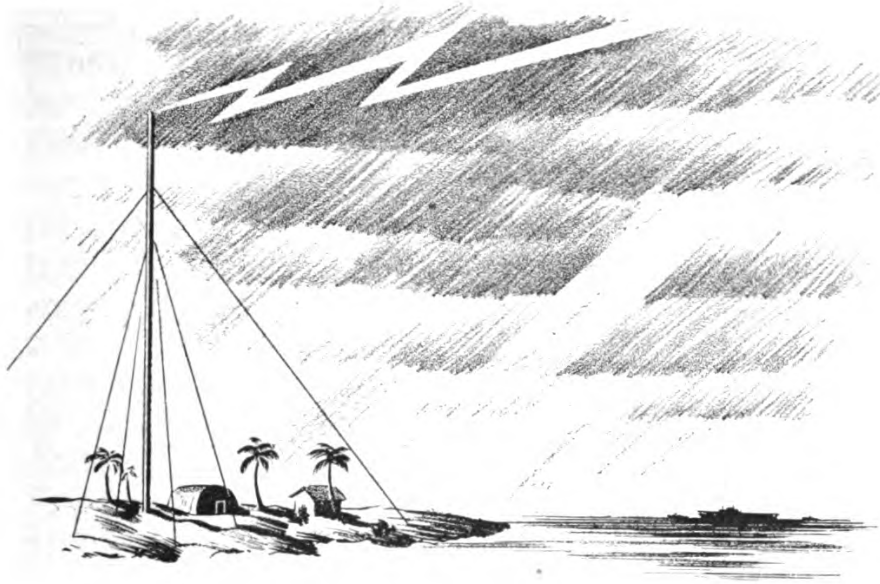
Because the next chapters are NOT a complete rehash and elaboration of all phases of the electricity you have studied, do not be confused into thinking the parts re-

viewed are the only ones of importance. The topics selected are those that are most frequently used in radio circuits. Special emphasis is placed upon pointing out WHERE, and also HOW these basic principles apply to the electronic circuits.

Much of the mathematics usually included in electronics technicians' courses, as taught in material schools, has been omitted from this course. Only the formulas and other information necessary for you to do your job have been included.

Some of the examples and illustrations will not immediately be meaningful. A few of the references to parts of a radio circuit will be strange, and still others may seem unnecessary, but you will gain an understanding of radio not so much in the study of the advanced concepts of radio, as in the study of the fundamentals of a.c. and d.c.

Therefore, after you have completed the study of these chapters, use them repeatedly as references to aid you in understanding WHY a certain part is used in a circuit, and HOW it performs its duty.



CHAPTER 2

CURRENT AND VOLTAGE

CONFLICTING CURRENTS

Two of the most controversial topics in all fields of electricity are—"What is Current?" and "Which way does it flow?"

Up to the time the vacuum tube was invented, the EXACT nature and the direction of current flow were not important. Motors would run, light bulbs would glow, and CORRECT answers to problems could be obtained—regardless of the assumptions that were made.

The vacuum tube changed the picture. Not only is it now necessary to establish a definite idea as to what an electric current actually is, but it is also necessary to clearly define the direction of its flow.

WHAT IS CURRENT?

Benjamin Franklin assumed that an electric current was a MOVEMENT of some kind of PARTICLES. He didn't know exactly what they were or how they moved, so it is no surprise that his original idea was in error.

It was the British scientist named Fleming who pointed out that an electric current is a DRIFT of FREE ELECTRONS through a conductor. Even the most violent objectors to the recent theory of electron flow agree that current is a drift of electrons.

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WHICH WAY DOES IT FLOW?

The big difference of opinion concerns the DIRECTION in which the electrons move. The old convention stated that electrons move from the positive to the negative poles. Those that advocate that idea point out that it is impossible for anything to move from a low to a higher potential. And since the positive terminal is the highest, current must flow downhill from positive to negative. This idea is amazing because it violates their own BASIC LAWS relative to the attraction of like and unlike charges.

First look at figure 4. Here two negatively-charged bodies REPEL each other, and two positive bodies will also repel each other. Since negative repels negative, it is impossible for electrons to flow toward the NEGATIVE TERMINAL of a battery or power supply.

Now reverse the situation. In figure 5, two OPPOSITELY-CHARGED bodies are brought near to each other. The result is a force of ATTRACTION between them.

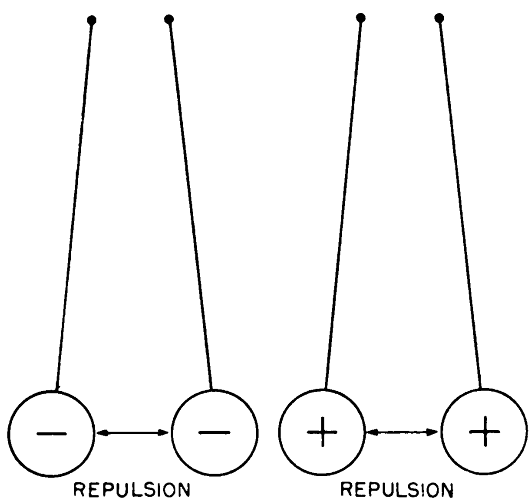


Figure 4.—Likes repel.

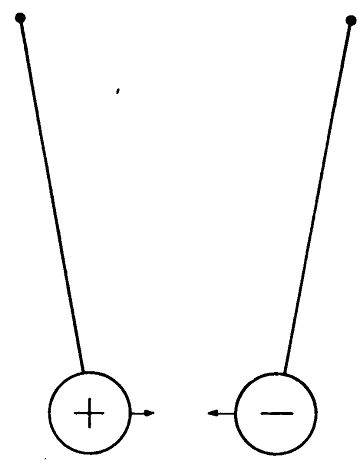


Figure 5.—Opposites attract.

From figure 5, it is not clear whether the negative moves toward the positive or the positive toward the negative, but a clear answer can be obtained for the situation within a conductor if you remember these facts—

First: In a conductor, ALL positive charges are fixed in the nucleus of the atom and cannot move.

Second: Approximately half the total number of electrons in an atom are contained in the orbits surrounding the nucleus. Of this number, a large percentage is FREE to move.

From these two facts, the answer is evident. Only the ELECTRONS can move freely, since the POSITIVE charges in a conductor are fixed.

In this manual as well as in most radio texts, current is defined as a DRIFT OF ELECTRONS IN THE DIRECTION OF A MORE POSITIVE POTENTIAL. An explanation of "more positive potential" will be given later.

CURRENT FLOW IN IONIZED LIQUIDS OR GASES

The flow of current in an ionized liquid or gas is slightly different then it is in a solid conductor, but it does not violate in any way the concept of electron movement.

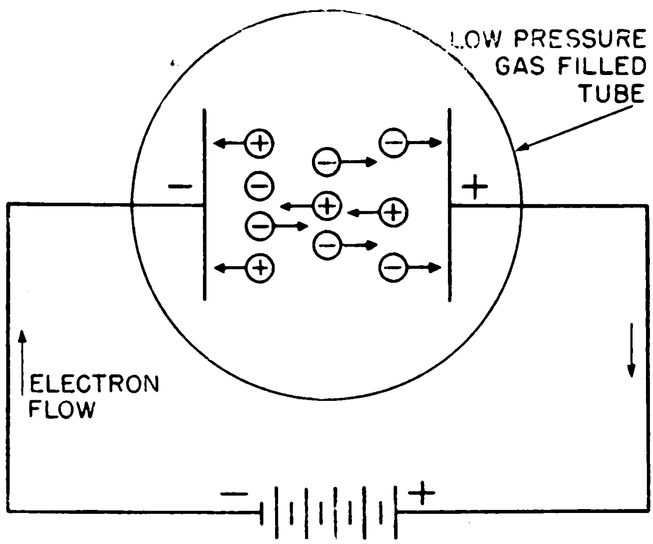


Figure 6.—Current movement in an ionized gas.

Just to remind you—an ION is a particle of matter that bears an electrical charge, either positive or negative. A POSITIVE ION is an atom that has lost one or more electrons. A NEGATIVE ION is an electron floating around in space.

Both the positive and negative ions resemble boats in water. They are free to move. The positive ion moves as an atom that has lost an electron or two. The negative ion is only a single electron that has been chipped off the atom.

In figure 6, if the positively-charged and negatively-charged plates are placed in a low-pressure gas-filled vacuum tube that contains ions, the electrons will drift toward the POSITIVE PLATE and into the battery.

The positive ions will move to the negative plate and

pick up free electrons from the plate. The free electrons NEUTRALIZE the positive ion and once more change the positive iron back into an atom.

The atom then floats into space and collides with electrons or other atoms. Again more electrons are knocked off the atom, forming MORE IONS, and setting the stage for a repeat performance.

What happened at the negative plate when the positive ion plucked off some electrons? More electrons rushed out of the battery onto the negative plate to try to restore the plate to its normal state. In the external circuit, the only current flowing is ELECTRONS out of the negative terminal of the battery, through the ionized gas, as explained, and back into the positive terminal of the battery.

In the basic electricity text, you were told that a single positive charge—a PROTON—is about 2,000 times as heavy as an electron. Since a positive ion is made up of several protons and the negative ion is a single electron, the weight of the WHOLE positive ion is THOUSANDS of times heavier than the negative ion.

Which will move the easier? The answer is like comparing the movement of a PT boat and a battleship. Naturally the lighter will move easier and with greater speed.

POTENTIAL AND VOLTAGE

Did you ever help load supplies? It requires real work to move cargo from the deck to the hold. But what has this cargo-moving to do with electricity? Call your available strength the POTENTIAL. The the WORK expended in moving the cargo is the VOLTAGE and the cargo you moved is equivalent to the CURRENT.

In other words, the available energy in the battery is its potential. The work done in moving electrons through a resistance is the voltage.

One volt represents the amount of WORK DONE by a battery or generator in moving one ampere of current through a resistance of one ohm.

Many times you have heard voltage defined as PRESSURE. That definition is satisfactory for basic work in electricity, but as you progress in the study of radio, you will find an increasing number of cases where this idea will fail to answer all the questions.

Eventually, you will abandon the pressure idea, so why not now? It is just as easy to think of VOLTAGE DROP as the amount of work done in moving electrons.

POSITIVE AND NEGATIVE POTENTIALS

A positive potential is created by REMOVING electrons. A negative potential is created by ADDING electrons to an object. To understand this principle look at figure 7.

RELATIVE POTENTIALS

OBJECT	ELECTRON CHARGE	VOLTAGE
A	50 removed	+50 v.
B	40 removed	+40 v.
C	30 removed	+30 v.
D	20 removed	+20 v.
E	10 removed	+10 v.
	(Grounded)	
F	0 removed	0 v.
G	10 added	−10 v.
H	20 added	−20 v.
I	30 added	−30 v.
J	40 added	−40 v.

Figure 7.—Relative potentials.

Object *A* has 50 electrons removed, *B* has 40, and so on down through *F*. *F* has an equal number of electrons, so it is neutral—neither positive or negative. Object *G* has an excess of 10 electrons, *H* an excess of 20 and so on.

Since the objects *A* through *E* have LOST electrons, they possess a POSITIVE charge. Object F has neither gained nor lost, and is NEUTRAL. All the others have GAINED electrons, so they bear a NEGATIVE charge. But all are not equally positive or negative. Object *A* is the most positive, *B* is next, then C, and so on for the rest of the column.

But how about object *G*—it has MORE electrons than *F*. So it will be more negative than *F*, and the same for the others down the line.

Since *F* is less negative than *G*, it may also be said that *F* is more positive than *G*. In the same manner, *G* is more positive than *H*, *H* more positive than *I*, and so on down the line.

According to this arrangement, an object is POSITIVE

to all those BELOW, or an object is NEGATIVE to all ABOVE.

It is possible for an object to be both positive and negative at the same time. Look at object *D*. It is negative with respect to *A*, *B*, and *C*, but is positive to all others below it.

Now change the electrons to volts. You cannot say that *A* is 50 volts positive, unless you use the term in connection with a REFERENCE POINT. Object A is 50 volts positive with respect to reference point *F*. Or *A* is 60 volts positive with respect to point *G*, 70 with respect to *H*, and so on.

If *E* is connected to ground, point *A* is only 40 volts positive with respect to the ground potential, while object

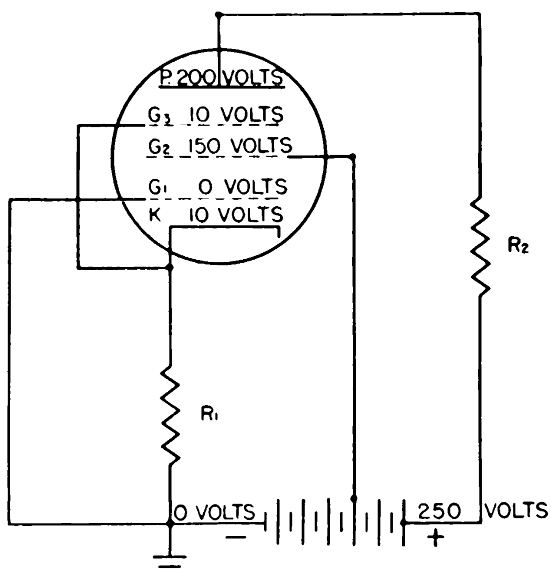


Figure 8.—Relative potentials in a vacuum tube.

F, which apparently had a NEUTRAL potential is negative 10 volts with respect to *E*.

Therefore, whenever you speak of a positive or negative voltage, YOU MUST USE IT WITH REFERENCE TO SOME OTHER POINT. In radio, the reference point is the potential of the chassis on which the radio is built. The potential of the chassis may be considerably above or below that of some other object. But when you say the plate of a vacuum tube is 200 volts positive or the grid is 10 volts negative, you merely express those voltages as compared to the voltage of the chassis. Later on you will find that the CATHODE of a vacuum tube is also commonly used as a reference point.

WHY USE RELATIVE POTENTIAL?

All radios have a great number of different potentials distributed throughout the circuit. A vacuum tube may have four or five different potentials at the same instant. Each potential is used to influence the operation of the tube. If any one potential changes with reference to the others, the action of the tube and the circuit may be changed completely. Figure 8 illustrates some typical potentials that exist within a single vacuum tube.

First the ground is considered to be at zero potential. Since the negative end of the power supply and G_1 are connected to GROUND, they too will be at zero potential.

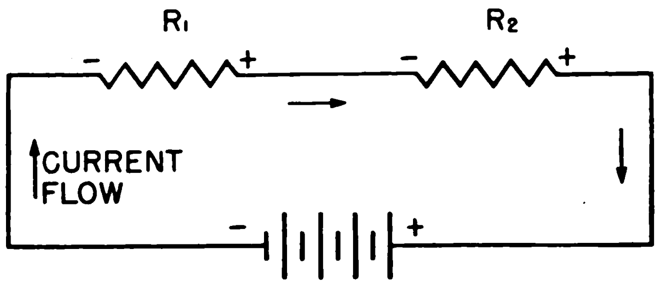


Figure 9.—Polarity of a resistor.

Current is flowing through resistor R_1, point K—cathode—is 10 volts more positive than ground.

When you compare the potential K to G_1, K is 10 volts positive with respect to G_1—or G_1 is 10 volts NEGATIVE with respect to K. Should K become 15 volts positive with respect to G_1, it would be the same as saying that G_1 is 15 volts negative with respect to K.

Put it another way. You and your buddy start for town without any money in your pocket. He finds a $10 bill on the sidewalk. Your pal is now $10 richer than you are OR you are now $10 poorer than he is. But the amount of money you have in your pocket is the same as you started with—NONE AT ALL.

In figure 8, G_2 is 150 volts positive with respect to GROUND, but only 140 volts positive with respect to K. G_3 is connected to K, so it is at the same potential as K.

Plate P is 200 volts positive with respect to ground, 190 volts positive with respect to K and G_3, but only 50 positive with respect to G_2.

As long as you work with radio, you will be using these relative potentials. Start getting acquainted with them now—the sooner you do, the easier your work will be.

WHICH IS THE POSITIVE END OF A RESISTOR?

A lone resistor, does not have either a positive or a negative end. It has polarity only when a current is flowing through it.

In figure 9, the arrows point in the direction that current is flowing. Since current always flows from negative to positive, the end at which the electrons ENTER the resistor is NEGATIVE, and the end at which they leave is POSITIVE. Remember that!—The end the current enters is negative. The end it leaves is positive in respect to the electrons that entered the resistor.

A–C AND D–C CURRENTS

Both a.c. and d.c. are used to operate power equipment. To connect some d.–c. motors to an alternating current would be disastrous, but in a radio, you'll usually have both a.c. and d.c. present in the circuit at the same time.

As you know, d.c. always flows in one direction. Never does it reverse and go the other way. It is not necessary

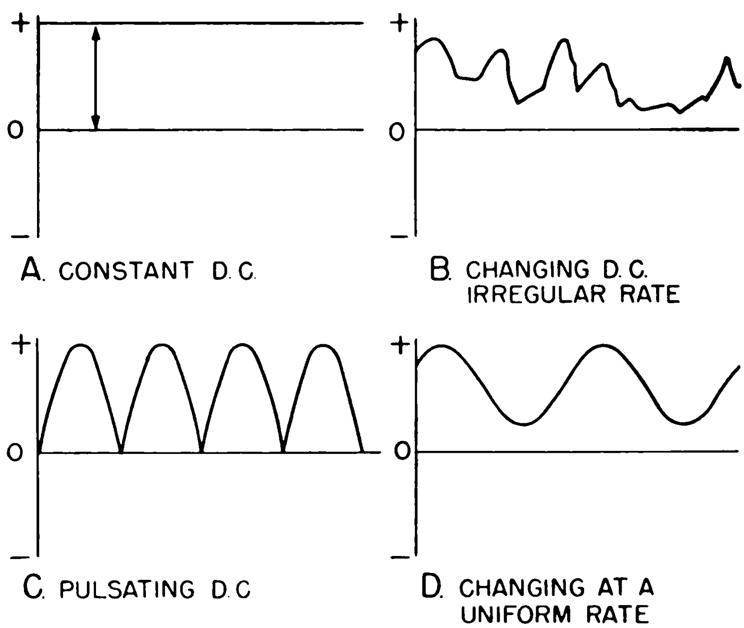


Figure 10.—Forms of d.c.

that the number of electrons flowing in a d-c circuit always be a constant value. Any value greater than zero will still make it d.c. It may have a steady constant value, or it may be pulsating at a great rate—just so long as it does not reverse its direction, it is not alternating.

Figure 10 illustrates four different forms of d.c. Only

A has a constant and steady value. The other three forms show a CHANGING d.c. Some may resemble the sine wave of a.c., but they are all d.c., because in none of these cases does the current flow in the negative—opposite direction.

An a.c. must flow in positive AND negative directions, as illustrated in figure 11. Although the waves in *A*, *B*, and *C*, differ in shape, all three are a.c., since they extend on BOTH sides of the zero line.

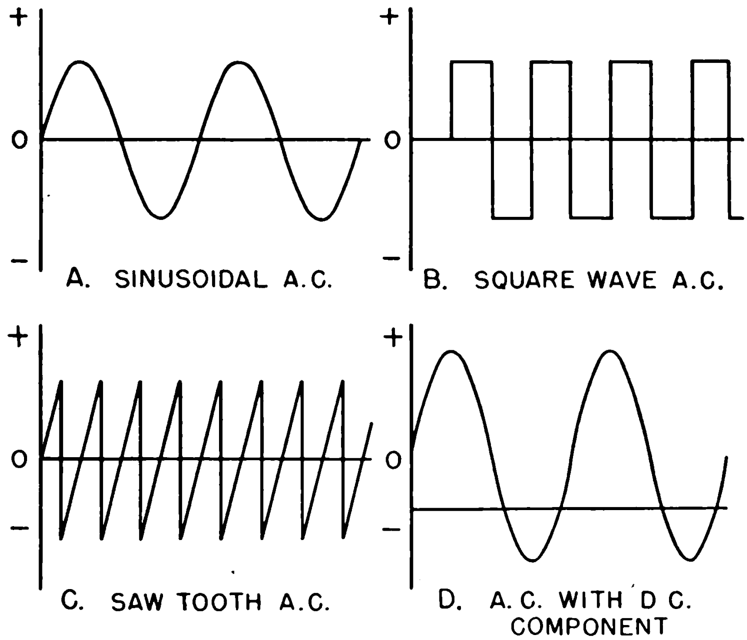


Figure 11.—Forms of a.c.

Figure 11D is slightly different. This wave lies on both sides of the zero line, but most of the wave lies on the POSITIVE side. This arrangement means that MORE CURRENT is flowing in the positive direction than in the negative direction.

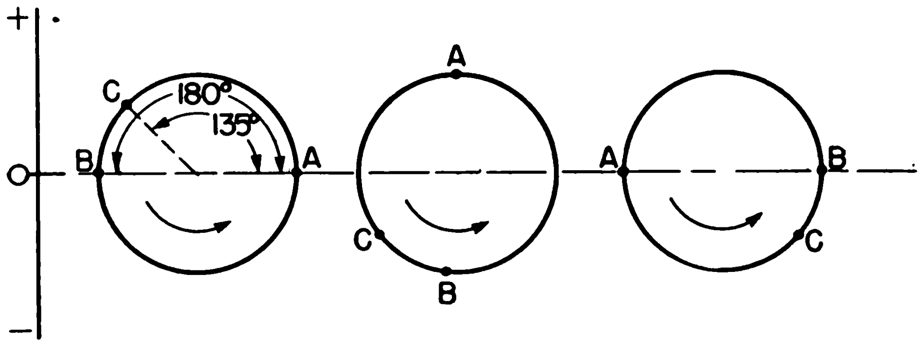
If 10 amperes flows in the positive direction, and six amperes flows in the negative, the net positive current will be four amperes. The net gain of four amperes is the d-c COMPONENT.

It is also possible to have more current flowing in the negative direction than in the positive direction. In this case, you will have a d-c current, but it will be a NEGATIVE COMPONENT.

PHASE RELATIONSHIP

Phase relationship is used to express a condition in which two moving objects are changing IN or OUT OF

STEP. Think for a moment of the opposite ends of a playground see-saw. When one end goes UP, the other goes DOWN. The two ends are OUT OF PHASE—because one end is rising while the other is falling.



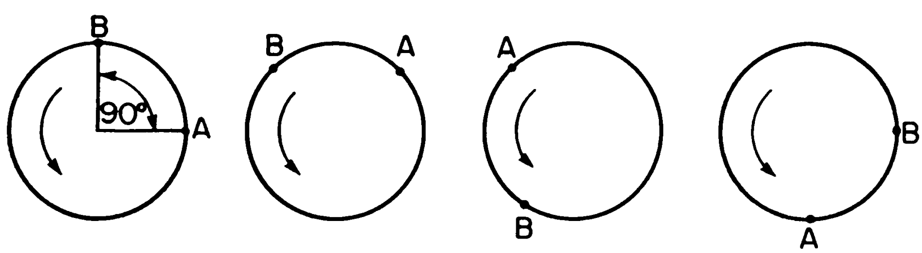
A B C

Figure 12.—Relationship between two points on a wheel 180 degrees out of phase.

In figure 12, *A* and *B* are two points on the circumference of a wheel that is rotating in a counterclockwise direction. Point *A* is going UP, and *B* is going DOWN. These two points are OUT OF PHASE.

How about point *C?* It is also going down, but is at a slightly different position than *B*. Therefore point *C* has a slightly different relationship to *A* than to point *B*.

Since the points are located on a circle, you can use the number of DEGREES of angular measurement to describe the location of *A* and the other two points.



A B C D

Figure 13.—Relationship of two points 90 degrees out of phase.

Point *C* is separated from *A* by 135 degrees, and *B* is separated from *A* by 180 degrees. Both points are out of phase with *A*, so you say that *B* is 180° and *C* 135° out of phase with point *A*.

The phase relationship of any point to any other on the circle may be given by indicating the number of degrees that separate the two points.

In figure 12*B*, if the upper half of the circle is described as PLUS and the lower half as MINUS, point *A* is maximum POSITIVE at the same time that point *B* is a maximum NEGATIVE. This describes two points that are 180 degrees out of phase.

Points *A* and *B* in figure 13*A* are separated by 90 degrees. As the wheel rotates, point *A* will always be 90 degrees behind point *B*. Point *B* is maximum positive, while *A* is zero. In figure 13*B*, *A* is rising and *B* is falling. In 13*C* both are falling at the same time. In figure 13*D*, point *B* is zero, while *A* is maximum negative.

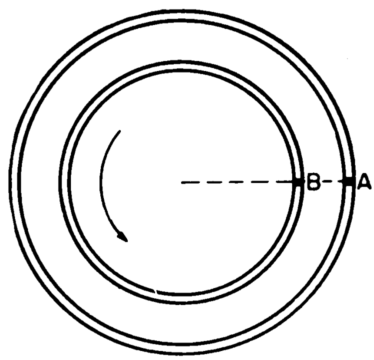


Figure 14.—Two points moving in phase.

When two objects are 90 degrees out of phase, one is either MAXIMUM POSITIVE or MAXIMUM NEGATIVE at the instant the other is ZERO.

In figure 14, points *A* and *B* are located on the same spoke of the wheel. Both will rise and fall at the same time. These two points are IN PHASE.

PHASE RELATIONSHIP AND SINE WAVES

You use SINE WAVES to represent phase relationship. Figure 15*A* shows the sine wave representations of two movements that are 180 degrees out of phase. Point *A* is maximum positive at the same instant that point *B* is maximum negative. Both *A* and *B* are zero at instant *X*.

In figure 15*B*, point *A* is maximum positive when *B* is zero, and *A* is zero when *B* is maximum in either the positive or the negative direction.

The sine waves in figure 15*C* show two motions that

are in phase. Both curves are maximum in the same direction at the same time, and both are zero at the same time.

WHERE PHASE RELATIONSHIP IS USED

Phase relationship can be used to show whether two voltages, or a voltage and a current, or two currents are increasing or decreasing at the same rate and at the same frequency.

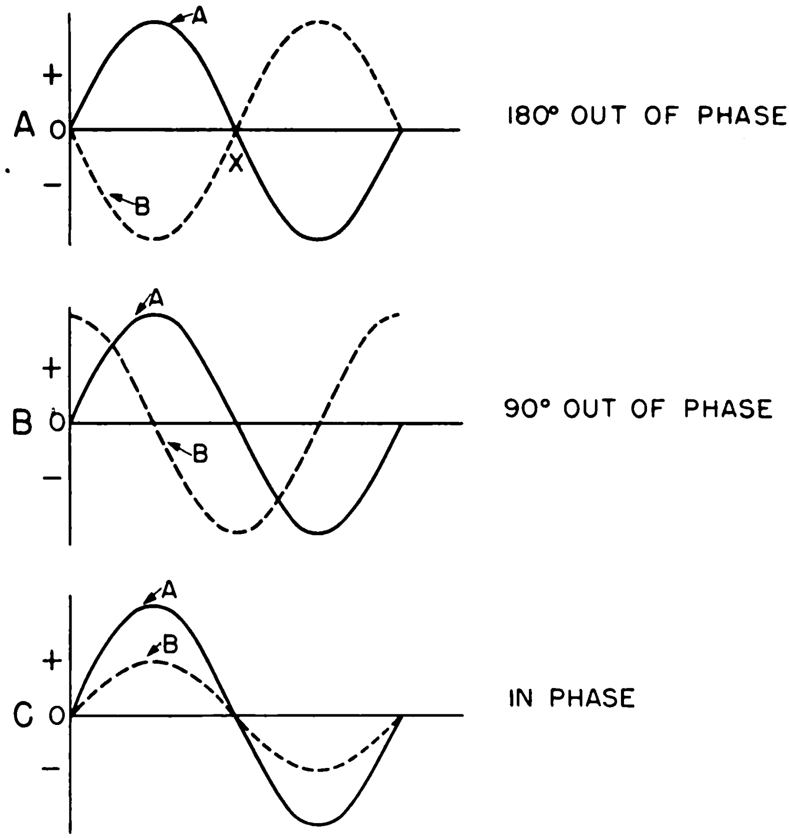


Figure 15.—Use of sine waves to show phase relationship.

The voltages in the primary and secondary of a transformer give a good example of two voltages 180° out of phase.

If the current flowing in the secondary of a transformer is increased, the current flowing in the primary is increased. This is an example of two currents that are IN PHASE.

You will soon learn that increasing the current flowing through a vacuum tube reduces the voltage on the plate of the vacuum tube. This is an example of a current and a voltage 180 degrees OUT OF PHASE.

CHAPTER 3

RESISTANCE

MORE ABOUT OHM'S LAW

The relationship of current and voltage in a resistance circuit is so simple that many of the important points are easily overlooked.

From Ohm's law, you learned that—

$$I = \frac{E}{R}$$

This seems simple. If you increase the voltage, or decrease the resistance, the current will increase. The current and voltage are always in phase. When the voltage is maximum, current is maximum; when voltage is minimum, the current will also be minimum.

RELATIONSHIP OF VOLTAGE TO RESISTANCE

So much for the relationship of current and voltage. But what about the relation of VOLTAGE to RESISTANCE? You say there is none—the voltage comes from the battery or generator, and has nothing to do with resistance.

Look at Ohm's law again. You can rewrite it as—

$$E = I \times R$$

Notice that the voltage is equal to the product of the current and resistance. If the resistance is equal to ZERO, the equation will be—

$$E = I \times O$$
$$E = O$$

or if the current is ZERO—

$$E = O \times R$$
$$E = O$$

Therefore, in any circuit, when the current or resistance is ZERO, the voltage is also ZERO. You still don't get "something for nothing."

A circuit without ANY resistance doesn't exist, but you can reduce resistance almost to zero by using a short piece of copper wire.

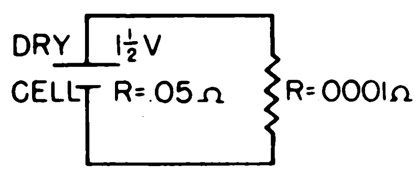


Figure 16.—Short circuit.

For instance, in figure 16 a dry cell is connected to an external circuit that has a resistance of 0.0001 ohm. The resistance of the cell is 0.05 ohm. The poles of the cell are made of carbon and zinc, and therefore are at a potential difference of 1.5 volts.

The resistance limiting the flow of current is equal to the sum of the resistances of the external circuit plus the internal resistance of the dry cell. In this case, the resistance of the external circuit is so small, 1 to 500, in comparison to the resistance of the cell, that you can omit it as a current limiting factor in the circuit. Hence, the current flowing in the circuit will be—

$$\frac{1.5}{0.05} = 30 \text{ amperes.}$$

This current flows through the external circuit, therefore the voltage drop across the EXTERNAL CIRCUIT will be—

$$30 \times 0.0001 = 0.003 \text{ volt.}$$

If the resistance of the EXTERNAL CIRCUIT is made EQUAL to the resistance of the CELL, the total resistance of the circuit will be

$$0.05 + 0.05 = 0.1 \text{ ohm.}$$

The current flowing in the circuit will be—

$$\frac{1.5}{0.1} = 15 \text{ amperes.}$$

The voltage drop in the external circuit will be—

$$15 \times 0.05 = 0.75 \text{ volt.}$$

If the resistance of the external circuit is made 100 ohms, the total circuit resistance will be—

$$100 + 0.05 = 100.05 \text{ ohms.}$$

The current flowing in the circuit will be—

$$\frac{1.5}{100.05} = 0.0149 \text{ ampere.}$$

The voltage drop across the resistance in the external circuit will be—

$$0.0149 \times 100 = 1.49 \text{ volts.}$$

The voltage drop across the cell due to the current will be—

$$0.0149 \times 0.05 = 0.0007496 \text{ volt.}$$

Here is a summary of the above example—

	R_{ext}	I	E_{ext}	E_{int}	
A	0.0001	30	0.003	1.5	*R* of the
B	0.05	15	0.75	0.75	cell equals
C	100.00	0.0149	1.49	0.0007+	0.05 ohm.

Look at line *A*. When the external resistance of the circuit is 0.0001 ohm, practically all the voltage drop due to the current occurs across the INTERNAL RESISTANCE of the cell, and only a small portion of the IR drop is across the resistance of the external circuit.

When the resistance of the external circuit and the cell are EQUAL, as in line *B*, you see that the voltage drop due to the current is divided equally between the two resistances.

See what happens in line *C*. The resistance of the external circuit is LARGE in comparison to the resistance of the cell. The voltage drop across the resistance of the

external circuit due to the current is 1.49 volts, but the IR drop across the cell due to the same current is only 0.0007 volt.

Here's what this table proves—When the internal resistance of the cell is large in comparison with the external resistance, PRACTICALLY ALL THE IR DROP OF THE CIRCUIT WILL APPEAR ACROSS THE CELL, but if the external resistance is large in comparison with the resistance of the cell, PRACTICALLY ALL THE IR DROP OF THE CIRCUIT WILL APPEAR ACROSS THE RESISTANCE OF THE EXTERNAL CIRCUIT.

To develop a large *IR* drop in the external circuit, make the resistance of the external circuit large in comparison with the internal resistance of the cell.

DEVELOPMENT OF A–C VOLTAGES

The resistance to a.c. follows all the rules for d-c resistance. In figure 17, the dry cell has been replaced by an a-c generator, and the voltage developed across the external resistance will be a-c instead of d-c. If the resistance is large, the voltage developed across the resistance will be correspondingly large.

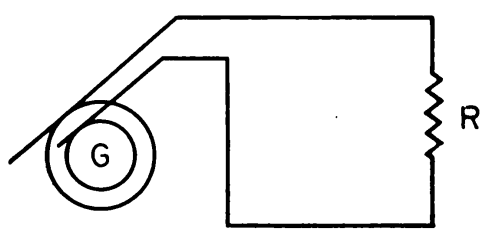


Figure 17.—Development of a.c. across the resistance.

With a.c., you can use impedances and resonant circuit to supply the external resistance.

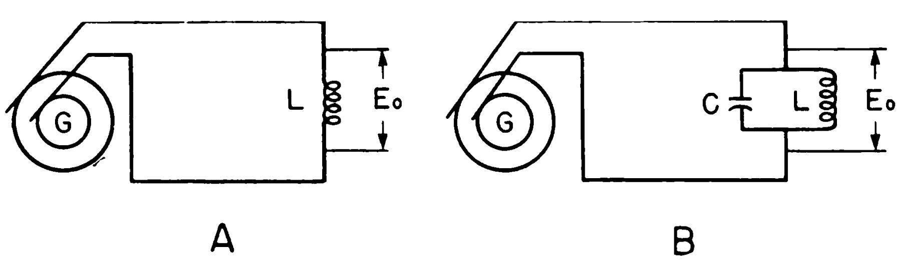


Figure 18.—Development of a.c. across an impedance.

Impedances of the type shown in figure 18 would fail to develop a d-c voltage of any magnitude because the d-c resistance of the coils is small. But both types would offer

a high impedance to a.c., and would develop a large a-c voltage.

In figure 18*A*, the impedance increases as the frequency rises, and the voltage developed across the external impedance also increases.

To develop the maximum voltage for ONE PARTICULAR FREQUENCY, use the parallel inductance-capacitance circuit of figure 18B. At the RESONANT FREQUENCY, this circuit will offer MAXIMUM IMPEDANCE and will develop the maximum voltage. You'll run into applications of these principles many times in this text.

POWER IN AN EXTERNAL CIRCUIT

Output stages of speech amplifiers and transmitters are called POWER AMPLIFIER stages. In these stages, instead of developing the maximum voltage across the resistance of the external circuit, you want to develop the maximum amount of power.

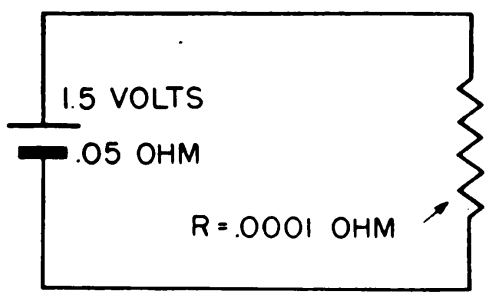


Figure 19.—Power developed across the external circuit.

In figure 19, a 1.5-volt battery with an internal resistance of 0.05 ohm is connected to an external resistance of 0.0001 ohm. The total resistance of the circuit is—

$$0.05 + 0.0001 = 0.0501 \text{ ohm.}$$

The current flowing in the circuit is—

$$\frac{1.5}{0.0501} = 30 \text{ amperes approximately.}$$

The potential developed across the external resistance is—

$$30 \times 0.0001 = 0.003 \text{ volt.}$$

The power developed is—

$$30 \times 0.003 = 0.09 \text{ watt.}$$

If the external resistance is increased to 0.02 ohm, the total resistance of the circuit is 0.07 ohm; the current flowing in the circuit is 21.4 amperes, and the power developed in the external circuit is 9.14 watts.

When the external resistance is progressively increased to 0.05, 0.07, and 100 ohms, the power developed in the external circuit will be 11.25, 11.00, and 0.22 watts.

All the values for the power developed in the external circuit for the various resistances are included in the following table:

R_{ext}	R_{int}	$WATTS_{ext}$	E_{ext}	I
0.0001	0.05	0.09	0.003	30
.02	.05	9.14	.428	21.4
.05	.05	11.25	.75	15
.07	.05	11.00	.88	12.5
100.00	.05	0.22	1.49	0.0149

The largest voltage is developed across the external resistance of the circuit when the external resistance is maximum and the current is minimum.

At the other end of the scale, the smallest voltage is developed when the external resistance is smallest and the current is greatest. But at the same time, the POWER developed in the external circuit is greatest when the resistance of the external circuit is equal to the resistance of the internal circuit. Notice also that when both resistances are equal to 0.05 ohm, neither current nor voltage is maximum. However, that is the point where the PRODUCT of the current and voltage is THE GREATEST.

Want to prove this statement further? Substitute any value between 0.0001 and 100 ohms for the external resistance. You will find that the power in the external circuit is greatest when the resistance of the external circuit is equal to the resistance of the internal circuit.

MATCHING IMPEDANCE

Again—what is true for d.c. is also true for a.c. Instead of matching resistances in a radio circuit, you will usually match IMPEDANCES. The transformer is commonly used to match the impedance of a vacuum tube circuit to the impedance of a load. To do this correctly,

the impedance of the primary must match the impedance —Plate Resistance R_p—of the vacuum tube, and the impedance of the secondary must match the impedance of the load.

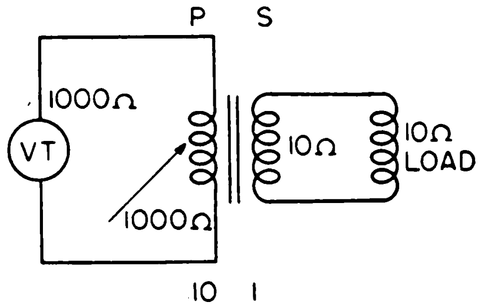


Figure 20.—Transformer used to match impedance between a vacuum tube and a load.

In figure 20, you are to use a transformer to match the impedance of a vacuum tube, to a 10-ohm load. The R_p of the tube is 1,000 ohms. To do this, the turns ratio between primary and secondary must permit the transformer primary to offer 1,000 ohms impedance to the vacuum tube, and the secondary to offer 10 ohms impedance to the load.

To start your calculation for finding the turns ratio, remember that—

$$(1) \quad \text{WATTS}_{\text{primary}} = \text{WATTS}_{\text{secondary}}$$

Using the power relationship—WATTS $= \frac{E^2}{R}$, or $\frac{E^2}{Z}$ for a.c.—

equation (*1*) becomes—

$$(2) \quad \frac{E_p^2}{Z_p} = \frac{E_s^2}{Z_s}$$

Collecting terms and extracting the square root, equation (*2*) becomes—

$$(3) \quad \frac{E_p^2}{E_s^2} = \sqrt{\frac{Z_p}{Z_s}}$$

Since the turns ratio between the primary and secondary is the same as the voltage ratio, equation (*3*) becomes—

$$(4) \quad \frac{Turns_p}{Turns_s} = \sqrt{\frac{Z_p}{Z_s}}$$

Substituting the 1,000-ohm primary and the 10-ohm

secondary from figure 20 in equation (*4*), the relationship becomes—

$$\frac{Turns_p}{Turns_s}=\sqrt{\frac{1{,}000}{10}}=\frac{10}{1}$$

Thus a step-down transformer with a turns ratio of 10 to 1 will correctly match the impedance of the vacuum tube to the impedance of the load for the most efficient operation.

Many times the last stage of an amplifier feeds into a transmission line, and the transmission line in turn feeds into a loudspeaker.

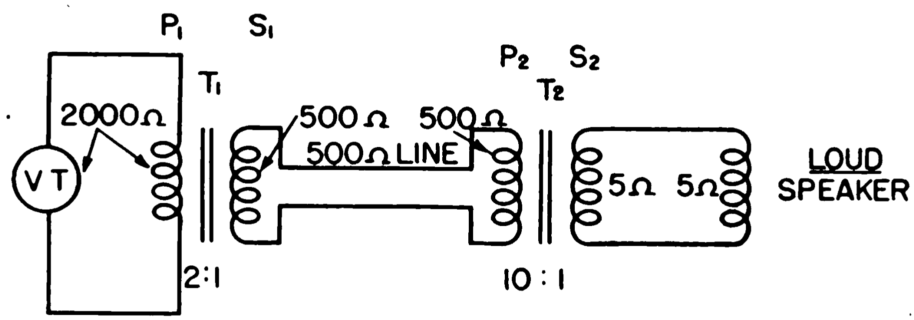


Figure 21.—Using transformers to match the impedance of an amplifier to a transmission line and a load.

In figure 21, the impedance of the vacuum-tube circuit is 2,000 ohms. This circuit is coupled by T_1 into a 500-ohm transmission line. Transformer T_2 couples the line to a 5-ohm voice coil.

Using equation (*4*), the turns ratio for T_1 will be—

$$\frac{T_p}{T_s}=\sqrt{\frac{2{,}000}{500}}=\frac{2}{1}$$

For T_2, the turns ratio will be—

$$\frac{T_p}{T_s}=\sqrt{\frac{500}{5}}=\frac{10}{1}$$

Output circuits of vacuum tubes are not the only circuits where you match the impedance. You'll use matched impedance in antenna coupling circuits, transmission lines, and many other places.

AN ELECTRICAL LOAD

It requires POWER to carry a load. To carry an INCREASED load, you must INCREASE the power that you are

using. The load on an electrical circuit may be a light bulb, a motor, a vacuum tube, or a loudspeaker. Anything that consumes power is a LOAD. When you increase the load, you increase the amount of power being used.

How do you increase the amount of power being used? In two general ways—

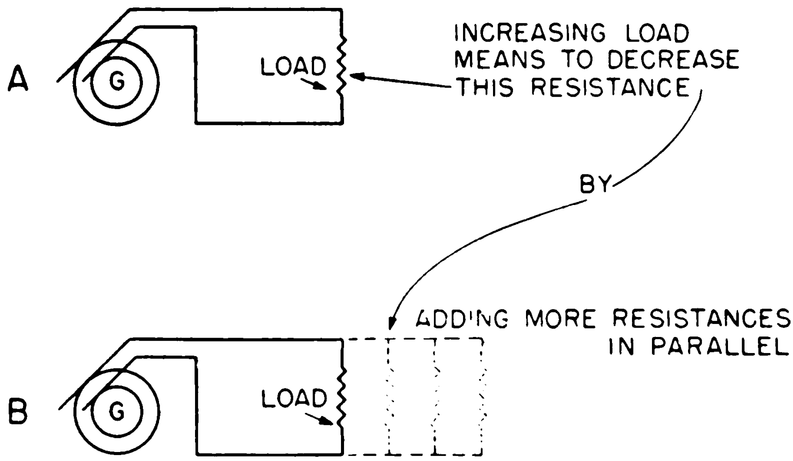


Figure 22.—Increasing the load on an electrical circuit.

Figure 22*A* shows the first method. Reduce the resistance of the circuit. Then the generator will have to furnish a larger amount of current, thereby increasing the load on the generator.

Figure 22*B* is the second method. ADD resistance in parallel with the resistances already in the circuit. This reduces the total resistance of the circuit, and the generator will have to furnish more current.

Therefore, an INCREASED LOAD causes an increase in current to be drained from the generator. You may increase the generator output either by decreasing the resistance of the load already in the circuit, or by adding resistance in parallel to the resistance already in the circuit.

In most cases, you'll refer to the resistance in the circuit as "the load of the circuit," but "increasing the load" DOES NOT mean that you increase resistance—it means that you decrease the resistance so that MORE current can flow out of the generator.

VOLTAGE DROPS AROUND A CIRCUIT

When you studied d.c., you learned about Kirchhoff's two laws. His second law reads something like this:

"The *IR* drops around a circuit are equal to the applied voltage." Radio is full of these closed circuits, and in every one you can START at the high voltage of the power supply, trace the *IR* drops around the circuit, and FINISH with zero voltage at the ground.

Figure 23 shows a circuit used in many radio hook-ups. You have vacuum tubes VT_1 and VT_2, five resistances, and a battery power supply.

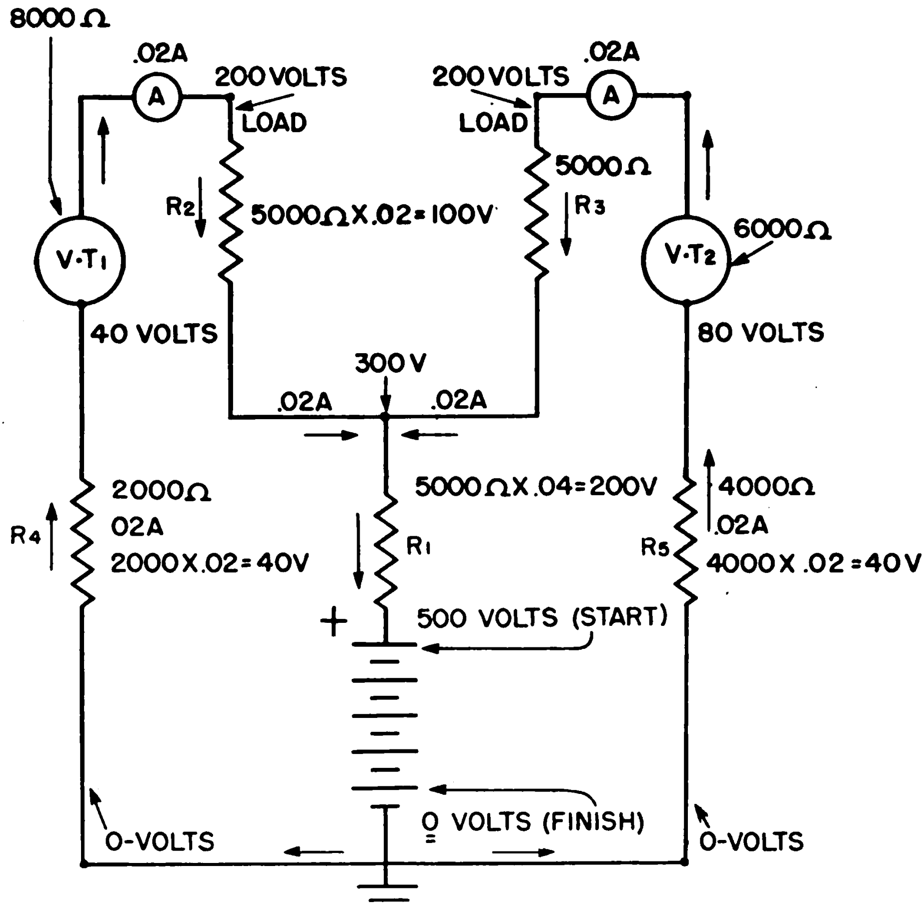


Figure 23.—IR drops about a closed radio circuit.

In the circuit of VT_1, the current flows out of the negative terminal of the battery, up through R_4 and VT_1, down through R_2 and R_1, and back to the battery. In the other leg of the circuit, the current flows out of the same negative terminal of the battery, up through R_5 and VT_2, down through R_3 and R_1, and back to the battery. Each leg of the circuit carries 0.02 ampere. Therefore, the current flowing through R_1 is equal to 0.04 ampere. The potential at the battery is 500 volts. Using the resistor R_1, you want to drop this voltage by 200 volts. Since there

is a current of 0.04 ampere flowing through it, the resistance must be—

$$\frac{200}{0.04} = 5{,}000 \text{ ohms.}$$

Since this resistor R is used to drop the voltage from 500 to the desired 300 volts, it is a VOLTAGE-DROPPING RESISTOR. It is used in most radio circuits.

The 300 volts are applied equally to R_2 and R_3. Each of these resistances is 5,000 ohms. The current flowing in each resistor is 0.02 ampere, therefore the voltage drop across each will be—

$$0.02 \times 5{,}000 = 100 \text{ volts.}$$

The voltage applied to each vacuum tube will be—

$$300 - 100 = 200 \text{ volts.}$$

Vacuum tube VT_1 has a d-c resistance of 8,000 ohms. With the current of 0.02 ampere, the drop across VT_1 will be—

$$0.02 \times 8{,}000 = 160 \text{ volts.}$$

The voltage at R_4 will be—

$$200 - 160 = 40 \text{ volts.}$$

Resistor R_4 is 2,000 ohms. The IR drop across it will be—

$$0.02 \times 2{,}000 = 40 \text{ volts.}$$

In the same way, you solve for the IR drops around the circuit of VT_2. When completed, the voltage drops around the circuit will be—

VT_1 CIRCUIT

RESISTOR	IR DROP
R_1	200
R_2	100
VT_1	160
R_4	40

TOTAL DROP = 500 volts

Applied E = 500 volts

VT_2 CIRCUIT

RESISTOR	IR DROP
R_1	200
R_3	100
VT_2	120
R_5	80

TOTAL DROP = 500 volts

Applied E = 500 volts

In each circuit, the SUM of the individual IR drops is equal to the applied voltage. If the resistance of VT_1

should drop from 8,000 to 4,000 ohms, as it may do in vacuum tubes, the total resistance will drop and a larger current will flow through the circuit of VT_1. Since each resistor is carrying a larger current, there also will be a larger *IR* drop across each resistor except VT_1. Because the vacuum tube has a lower resistance, it will have a lower *IR* drop than before.

This process of increasing and decreasing the resistance of the vacuum tube is used to create larger *IR* drops across load resistance R_2, figure 23. This gives you the basis for amplification in a radio circuit.

EFFECTIVE RESISTANCE

In the chapter on RESONANCE, you heard about the effective resistance of a circuit. This is a term used to describe ALL FORMS OF RESISTANCE—NOT IMPEDANCE—that tend to slow up the flow of current in a circuit.

With d.c. and low-frequency a.c., the only resistance to the flow of current is the OHMIC resistance of the wire. But at HIGH FREQUENCY, several other kinds of resistance appear and are of considerable importance in radio circuits. You will usually hear these resistances called *r-f* resistances.

SKIN EFFECT

Skin effect is one of the r-f resistances. At high frequency, the current does not move through the center of the conductor, but has a tendency to travel on or near the surface of the conductor. The higher the frequency, the farther out from the center of the conductor the current flows.

The cause of this surface transmission of h-f currents is easy to explain. Most electrical conductors are made of NON-MAGNETIC metals, such as copper and aluminum. From your experiments with magnetism, you remember that these materials offer a high RELUCTANCE to the flow of magnetic flux. A piece of copper placed in a magnetic field will actually force away or repel the magnetic field.

The second point to remember is that any conductor carrying a current is surrounded by a magnetic field. A conductor made of IRON or STEEL will be surrounded by the field, and the field will also PASS THROUGH the conductor. A COPPER conductor will also be surrounded by

a field, just as was the iron conductor. But the field will PENETRATE the copper wire only with great difficulty.

In figure 24, the heavy line is the surface of a solid copper conductor. The three rings OUTSIDE of the conductor represent the normal magnetic field caused by the r-f current flowing through the conductor. Notice that they are equally spaced and not crowded together. The three rings INSIDE the circumference of the conductor represent the interval magnetic field, and are NOT equally spaced. They are crowded together near the surface. This crowding is caused by the reluctance of the copper to permit the flux to penetrate the copper. Because of this reluctance, the current is forced to the SURFACE of

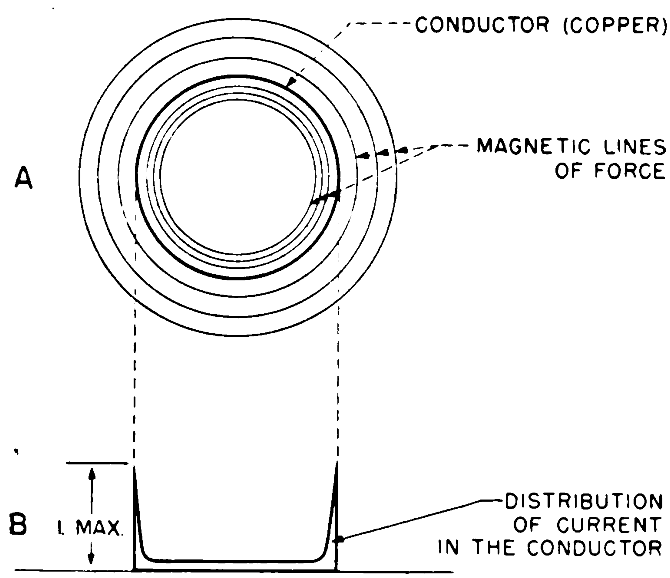


Figure 24.—Distribution of r-f current in a solid copper conductor.

the conductor. Figure 24*B* is a graph of the distribution of current in a solid copper conductor. The maximum current is AT THE SURFACE of the conductor.

What's wrong with allowing the current to travel on the surface of the conductor? First, the external magnetic field will be much stronger because the current is concentrated at the surface of the conductor. Second, this stronger field will LINK itself with a greater number of other fields, and produce a larger counter-electromotive force. It is this additional counter-emf that gives the effect of added resistance in the conductor. In coils whose windings are close together, the resistance caused by skin effect are more pronounced.

OVERCOMING SKIN EFFECT

Since skin effect is more pronounced in non-magnetic copper or aluminum conductors than in iron or steel, the solution to the problem would seem to be the use of iron or steel wires. But—the added d-c resistance of the iron wires would more than offset what you'd gain by reducing the skin effect. Since the CENTER of the non-magnetic conductor causes all the trouble, the simplest solution is to remove the center. Use a hollow tube for a conductor.

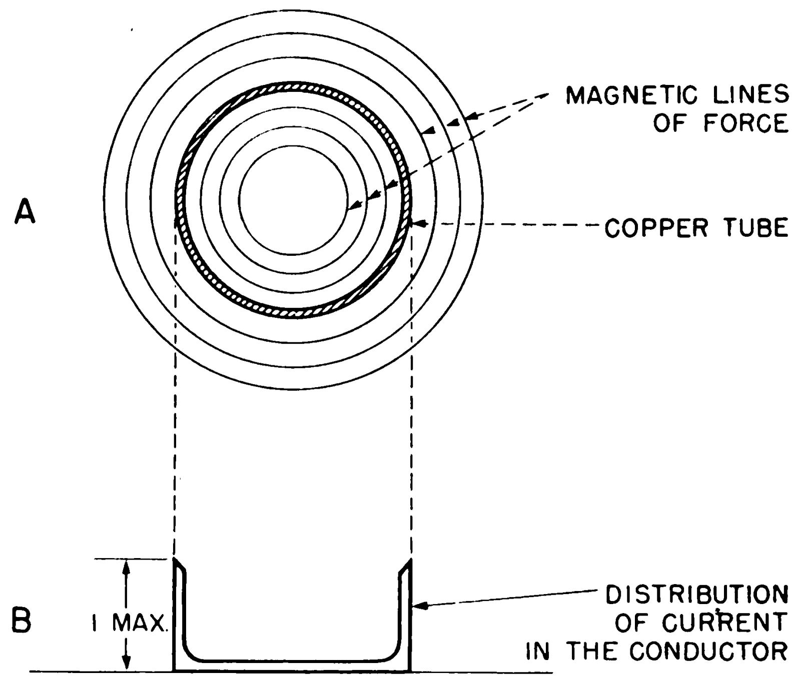


Figure 25.—Reduction of skin effect by using copper tubing.

Figure 25*A* shows the arrangement of the field in a COPPER TUBE. Notice that the lines of force inside the tubing are not crowded, and are equally spaced. In 25*B*, the distribution of current in the conductor, is shown. The flow is slightly greater on the outer than on the inner surface. By this arrangement, the skin effect is materially lessened.

Another method of reducing the skin effect is the use of fine wires. In order to get the necessary current-carrying capacity, a number of these fine wires are braided together to form a cable. One type of braided cable is LITZ WIRE.

CHAPTER 4

RESISTANCES IN RADIO CIRCUIT

MANY TYPES FOR MANY NEEDS

Resistances are used in radio circuits for many purposes. Chief among these uses are to—

Drop a voltage.
Develop a voltage.
Isolate or separate one stage from another.
Provide a source for several different voltages.
Couple together two units of a circuit.

As you progress in the study of radio, you will find many places you desire to REDUCE the voltage between one point and another. You do this by inserting a resistor in the line to drop the voltage.

Many times, as in the PLATE CIRCUIT of an amplifier, you will use a resistor to develop a voltage. This is done by inserting a resistor so that the change in current will create a changing voltage to be passed on to the next tube.

It is frequently necessary to connect several units to the same power supply line. If this were done directly without using a resistor to separate each unit, the operation of one stage would affect the operation of the other.

Large resistors are usually placed across the OUTPUT of a power supply. This resistor acts as a PARTIAL LOAD and also a source for other potentials. One side of this

resistor will be at maximum positive, and the other side will be at ground potential. By tapping into the resistor at points between the maximum positive and ground, a variety of voltages between ground and maximum positive can be obtained. This resistor is called a VOLTAGE DIVIDER.

You will find many uses for the resistor other than those listed. But wherever you see them, remember that they are placed in the circuit for a definite purpose—not just to make the set complicated.

TYPES OF RESISTORS

Resistors are divided into two major classes—FIXED and VARIABLE, with several subdivisions of each class.

Figure 26.—Schematic symbol for resistors.

In schematics, the various types of resistors will appear as shown in figure 26. Fixed resistors appear as single wavy lines. The variable resistors have several different

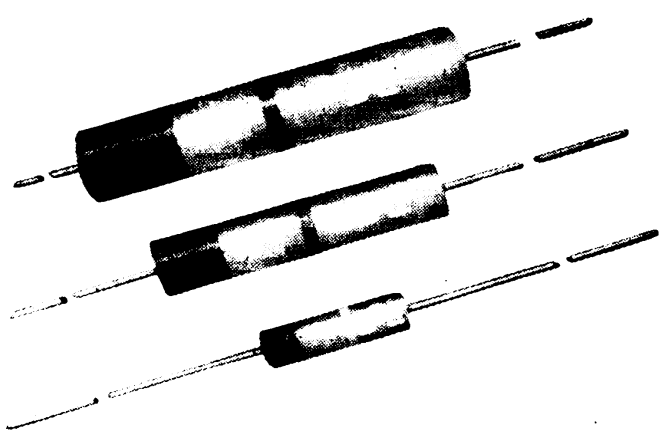


Figure 27.—Carbon resistors.

symbols. The rheostat and the potentiometer are illustrated in figure 33. Each of these types will be discussed further in this chapter.

FIXED RESISTORS

There are two types of fixed resistors—the CARBON resistors shown in figure 27, and the WIRE-WOUND type, shown in figure 28. There are several sizes of each type.

Carbon resistors are made by mixing measured amounts of carbon and clay, forming or shaping the mixture, and then fusing or burning the shapes into a solid mass. The amount of carbon added to the clay depends upon the resistance required. Carbon resistors are of two forms—AXIAL having pig-tails extending outward from the ends, and RADIAL with the terminals wrapped around the ends of the resistor. The radial type is illustrated in figure 29 and the axial type in figure 30.

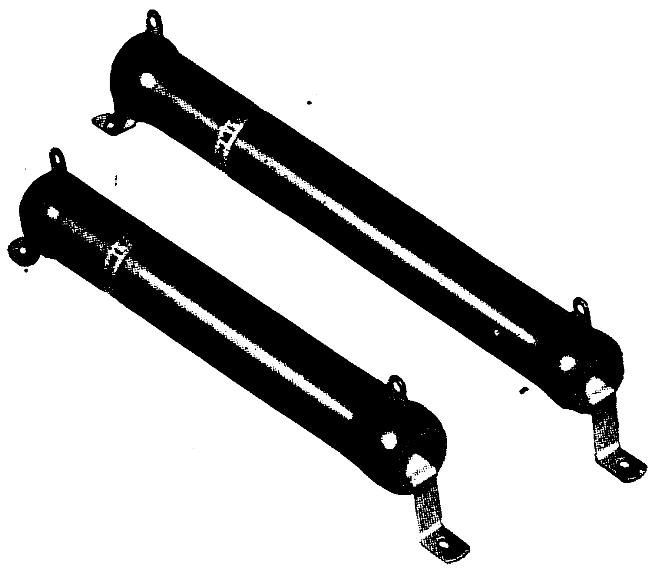


Figure 28.—Wire wound resistors.

The resistance of a carbon resistor will vary from a few ohms to several megohms. You will find that the power ratings vary from about ¼ watt to about 5 watts.

COLOR CODE FOR RESISTORS

A system of colors is used to show you the rated resistance of carbon resistors. It is based upon assigning a COLOR to each number of the numeral system. Instead of writing the numbers on the resistors, the colors are painted on. To find the value of a resistor, you look at the colors and apply the code to read the numbers. Here are the colors and the numbers they represent.

The radial resistor in figure 29 is identified by having the body of the resistor a solid color with a DOT near the middle of the body. A third color is on one end of the resistor. You read the colors in this order—BODY-END-DOT.

COLOR CODE FOR CARBON RESISTORS

COLOR CODE

BLACK	0
BROWN	1
RED	2
ORANGE	3
YELLOW	4
GREEN	5
BLUE	6
VIOLET	7
GRAY	8
WHITE	9

TOLERANCE (Accuracy)

BROWN	1%
RED	2%
ORANGE	3%
YELLOW	4%
GREEN	5%
BLUE	6%
VIOLET	7%
GRAY	8%
WHITE	9%
GOLD	5%
SILVER	10%
NO COLOR	20%

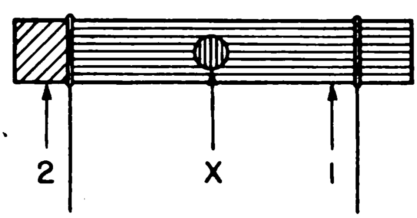


Figure 29.—Color code on a radial resistor.

This is what these colors means—

(*1*) BODY —— Indicates the first digit.
(*2*) END —— Indicates the second digit.
(*X*) DJT —— Indicates number of zeros to be added to the other two digits.

If the body color (*1*) is GREEN, the first digit of the resistance is "5." The end color (*2*) is YELLOW. That color means "4," so the second digit is "4." You now have the first two digits—54.

The dot (*X*) is red, hence the dot indicates the number of zeros to be added to the 54, and red stands for "TWO ZEROS." The full value of the resistance will be—5,400 ohms.

Here is another example—

BODY —— Red
END —— Green
DOT —— Yellow

Red stands for "2." The green end indicates a "5," and the yellow dot tells you to add "4 zeros" to the 25. You get—250,000 ohms.

Try this one—

BODY —— Brown
END —— Green
DOT —— Black

Brown stands for "1," the green is "5," but the black dot tells you to add "zero number of zeros." So you will have a resistance of 15 ohms. Remember—any resistor with a BLACK DOT is less than 100 ohms.

Suppose the resistor has "no dot." That means that the dot is the SAME color as the body. To illustrate, look at this—

BODY —— Yellow
END —— None (Yellow—same as body)
DOT —— None (Yellow—same as body)

In this case the WHOLE RESISTOR IS YELLOW. You have three yellows, and you will read it as: BODY—4, END—4, and DOT—4 zeros. The resistance will be 440,000 ohms.

A splotch of silver any place on the resistor will indicate 10 percent accuracy, and a splotch of gold will tell you that its resistance rating is within 5 percent of being accurate. No gold nor silver means that it is within 20 percent of being accurate.

COLOR CODE ON AXIAL RESISTORS

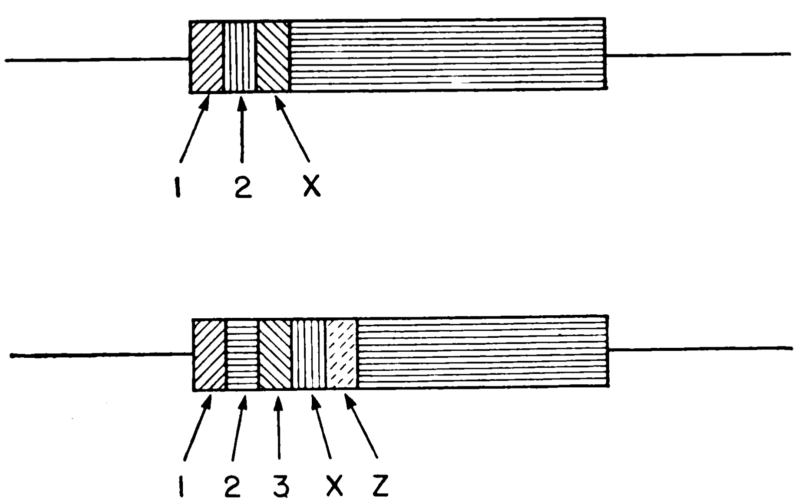


Figure 30.—Color code for axial-type resistor.

The only difference between the reading of the RADIAL and the AXIAL resistor color codes is in the way the colors are placed on the resistors. In figure 30, the colors of the AXIAL resistor are placed in order from the END TOWARD the CENTER. Regardless of the way the resistor is turned, start with the end color and read toward the center. The order in reading in indicated by *1, 2, 3, X,* and *Z.*

These colors mean—

COLOR NUMBER	MEANING
1	First digit
2	Second digit
3	Third digit
X	Zeros to be added
Z	Accuracy (Tolerance)

Here is how it is done. In figure 30 the colors are—

POSITION	COLOR	DIGIT
1	ORANGE	3
2	VIOLET	7
3	GREEN	5
X	RED	00
Z	WHITE	8%

So—RESISTANCE = 37,500 ohms TOLERANCE = 8%

It is difficult to make a mistake in reading the value of a resistor using the axial system, but always start at the OUTSIDE and read INWARD.

CARBON RESISTOR POWER RATINGS

Practically none of the carbon resistors has its POWER RATING indicated by either color or printed information on the body of the resistor. But there is a simple and fairly accurate way of estimating this power rating by measuring the SIZE of the resistor. Since a larger resistor can be expected to carry more current, the table on page 41 may help you.

This table may not be absolutely accurate, but many times you will be called upon to replace a burned-out resistor that has been completely discolored by heat. In

that case, your only guide is your knowledge of the radio circuit and the dimensions of the resistor.

LENGTH OF RESISTOR	BODY SIZE	WATTAGE
2 inches	pencil	2 to 3 watts
2 inches	slim	2 watts
1 inch	pencil	1 watt
½ inch	pencil	½ watt
½ inch	slim	¼ watt

WIRE-WOUND RESISTORS

Wire-wound resistors are made by winding a high-resistance wire on a porcelain tube. The amount of resistance is regulated by the SPECIFIC resistance of the wire and the length used. The windings are protected from damage by another coating of porcelain over their surface.

Wire-wound resistors are designed to dissipate large amounts of heat without damage to themselves. But it is important when installing one that it be a small distance from other elements in the circuit, since the heat produced may cause considerable damage to insulation of other elements.

RESISTANCE AND POWER RATINGS

The resistance and the power ratings of wire-wound resistors are indicated by printed tags attached to the resistor. Sometimes metal bands are used to show the ratings. These bands will show the resistance value even after considerable burning. Other resistors have paper tags that always suffer complete obliteration of information when the resistor overheats. Familiarize yourself with the approximate values of the main resistors in your radio sets. In an emergency, you'll get credit for being on the ball!

BLEEDER RESISTORS AND VOLTAGE DIVIDERS

As you know, it is a usual practice to connect a large wire-wound resistor across the output of a power supply. This resistor acts as a PARTIAL LOAD and also DISCHARGES the electrolytic filter condenser. Figure 31 shows two common types. Voltage dividers are wire-wound. Except

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for a narrow bare strip, the tube and windings are encased in porcelain. The bare strip permits the clamps to make contact with the wires, and allows you to TAP-OFF various required voltages.

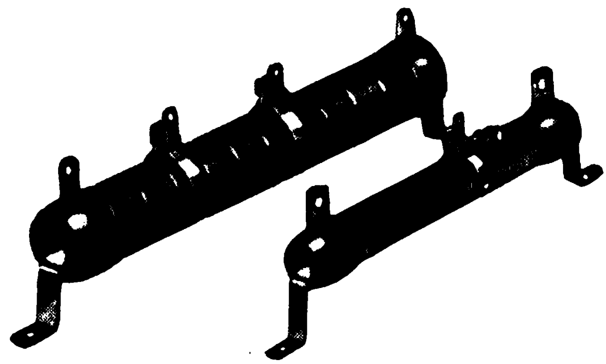


Figure 31.—Voltage divider and bleeder resistor.

You can compare a voltage divider to a ladder. The TOP of the ladder has a potential of 500 volts. The BOTTOM of the ladder is at zero potential. If the steps of the ladder and resistance are spaced uniformly, you can assume that the potential will be 250 volts HALF-WAY DOWN the ladder. The ladder will have a potential of only 200 volts three-fifths of the way down, and so on for any rung on the ladder.

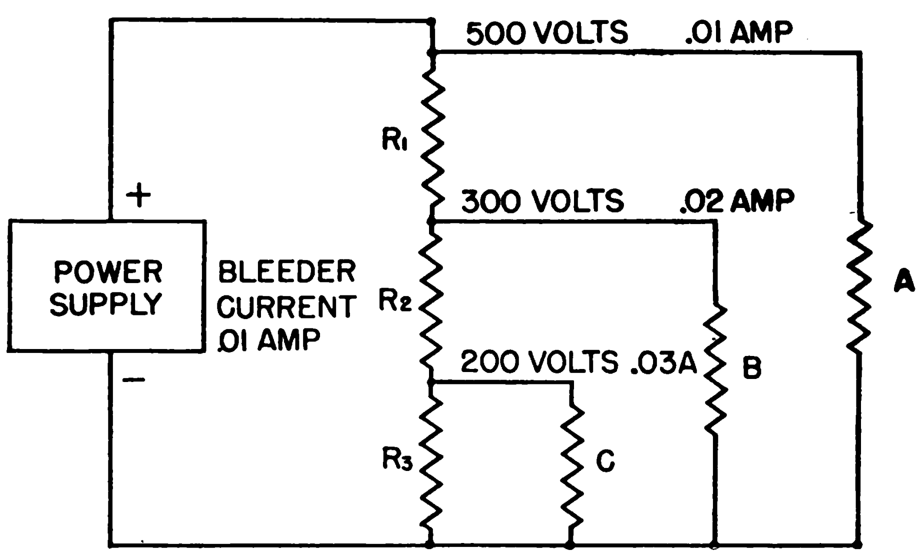


Figure 32.—Voltage divider circuit.

The voltage divider in figure 32 has three taps. You wish to deliver 500 volts with a current of 0.01 ampere to load *A*. Load *B* requires 300 volts with 0.02 ampere, and load *C* operates at 200 volts with a current of 0.03

ampere. The current carried by the bleeder is 0.01 ampere.

A problem of this type requires that the bleeder have the correct resistance and power rating. To solve this problem, you must consider all the currents in the circuit in the following manner—

THE CURRENT FLOWING IN—

$$I_{R_3} = 0.01 \text{ ampere, BLEEDER current.}$$

$$I_{R_2} = I_{R_3} + I_C = 0.01 + 0.03 = 0.04 \text{ ampere.}$$

$$I_{R_1} = I_{R_2} + I_B = 0.04 + 0.02 = 0.06 \text{ ampere.}$$

Current I_A of load A does not flow through the bleeder, and does not enter into the calculation of the bleeder resistance.

Total current through the bleeder is 0.06 ampere. All this current flows through R_1. The currents through the individual resistances are found as follows:

RESISTORS	CURRENT IN AMPERES	RESISTANCE IN OHMS
R_3	0.01	$\frac{200}{0.01} = 20{,}000\ \Omega$
R_2	0.04	$\frac{100}{0.04} = 2{,}500\ \Omega$
R_1	0.06	$\frac{200}{0.06} = 3{,}333\ \Omega$
	TOTAL RESISTANCE	$= 25{,}833\ \Omega$

A resistance of 25,833 ohms is not a stock resistor, so you will choose a resistor of 25,000 ohms. It will be close enough, since most resistors are only accurate to about 5 per cent.

BLEEDER RESISTOR POWER RATINGS

The POWER RATING of a resistor is equally as important as its resistance. A resistor that is not able to dissipate the required amount of power will soon heat up and burn out. Here is how to make sure that your resistor is large enough—

Look at figure 32 again. Resistor R_1 is carry 0.06 ampere of current. The voltage drop across this resistor is 200 volts. Therefore, the power dissipated by R_1 is—

$$200 \times 0.0\dot{6} = 12 \text{ watts.}$$

Resistances are rated by the WATTS OF POWER they dissipate over their entire length. In this case, resistance R_1 is 3,333 ohms. This is about one-eighth of the resistance of the entire bleeder. Therefore, for R_1 to be able to dissipate this amount of power, the whole resistor must be able to dissipate—

$$12 \times 8 = 96 \text{ watts.}$$

Bleeder resistors usually burn off at the ends if the heat-dissipation factors are not taken into consideration.

VARIABLE RESISTORS

Radio circuits make use of variable resistors for volume controls, gain controls, some types of tone controls, and in a great number of other circuits where it is necessary to change the operation of the circuit periodically.

Do not be confused into thinking that every dial you turn is connected to a variable resistor. Many knobs are connected to variable condensers, inductances, and rotary switches.

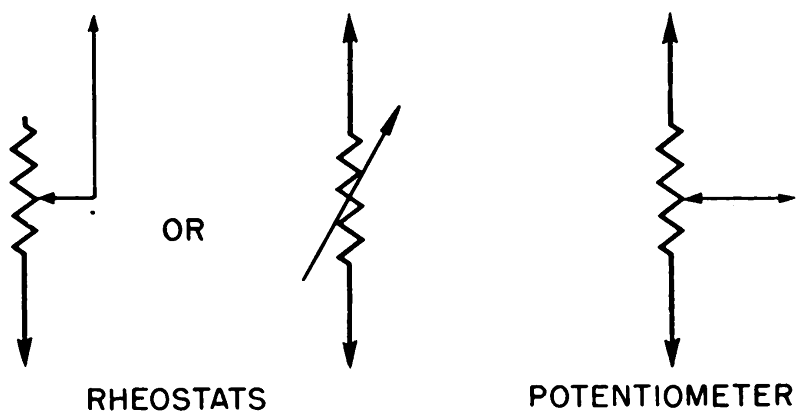


Figure 33.—Variable resistor.

Figure 33 shows one type of variable resistor. Whether it is a potentiometer or rheostat depends upon HOW it is connected into the circuit. More will be given on this later in this chapter.

The structure of a wire-wound variable resistor is illustrated in figure 34. This construction is used in most wire-wound variable resistors.

Figure 35 shows several styles of variable resistors commonly used as volume controls. The resistance in this type is usually supplied by a compound of CARBON

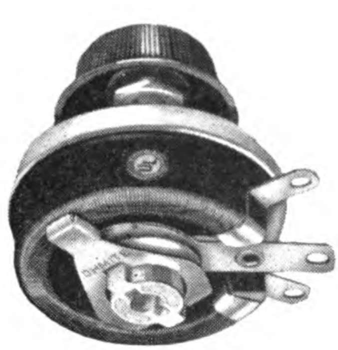


Figure 34.—Structure of a wire-wound variable resistor.

painted on a fiber disk. The movable arm may be a roller or a metal "tilt disk" that makes contact with the

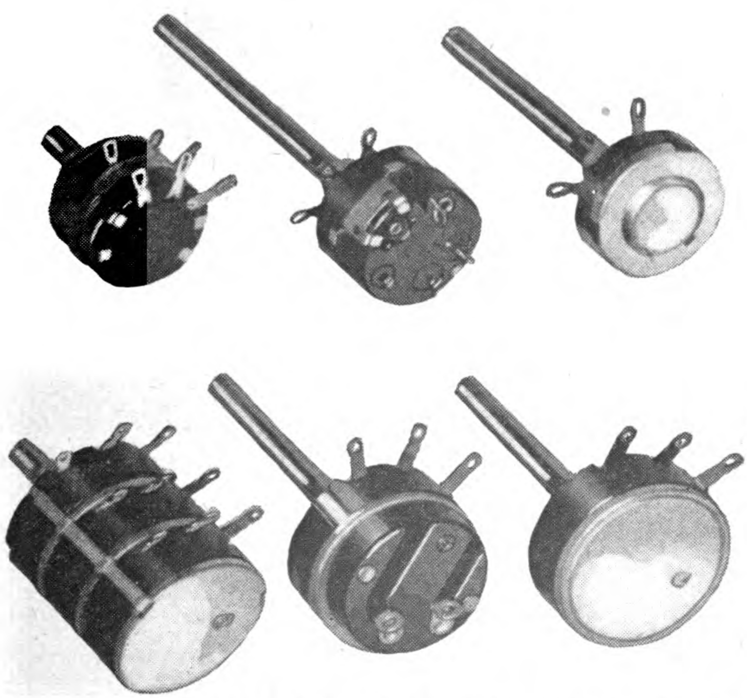


Figure 35.—Types of variable resistor commonly used as volume controls.

carbon coating. Turning the knob moves the contact between the maximum and minimum values of resistance.

RHEOSTAT OR POTENTIOMETER

Look again at figure 33. Observe that the variable resistor has THREE terminals, one at each end of the resistance and a third one connected to the movable arm.

If ONE END and the movable arm are connected as shown in figure 36, the variable resistor is a RHEOSTAT. Notice that one end of the resistor is left unattached.

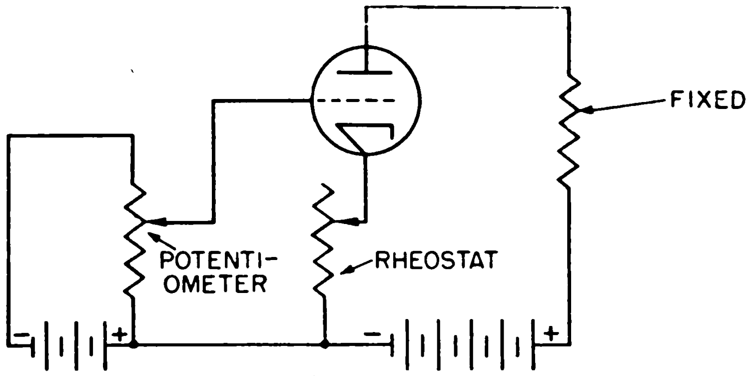
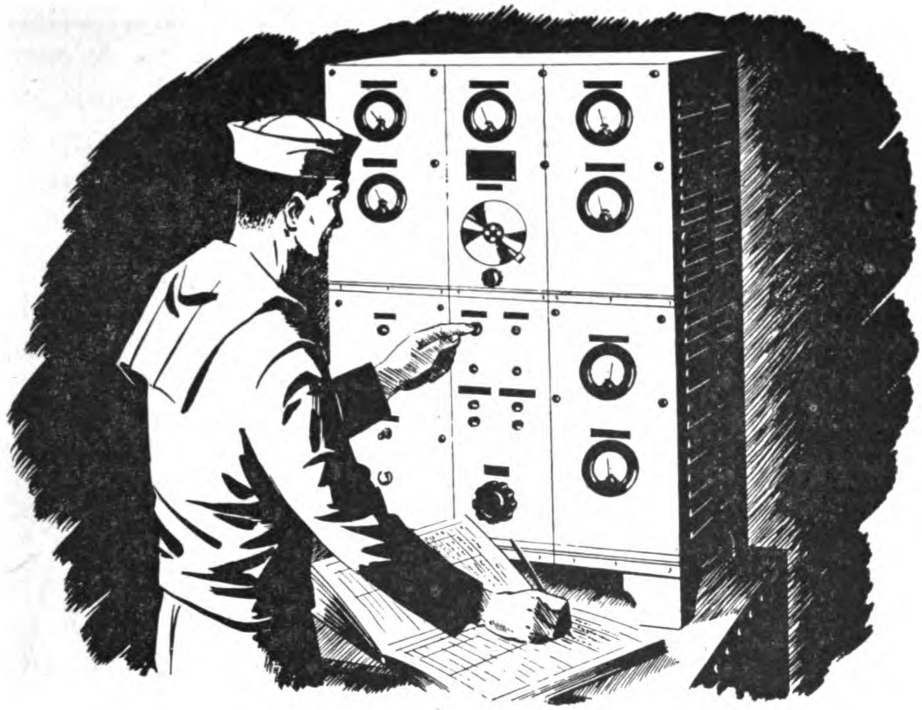


Figure 36.—A variable resistor used as a rheostat and a potentiometer.

If BOTH ENDS of the resistor are connected into the circuit, and the movable arm is connected to another element, the variable resistor is a POTENTIOMETER.



CHAPTER 5

INDUCTION

THE MAGNETIC FIELD

You recall from your study of electricity that a conductor carrying a current is surrounded by a magnetic field.

As shown in figure 37, the magnetic field is DIRECTIONAL. If the direction of the current flow is reversed, the direction of the field is also reversed. In figure 37*A*, the current is flowing UPWARD, and the compass needle indicates that the field is CLOCKWISE in direction. In figure 37*B*, the current is flowing in the opposite direction, and the field has also reversed itself.

Connect a circuit as indicated in figure 38. Close the switch. The voltmeter and ammeter will indicate that a current is flowing through the circuit. Thus the connection wires, as well as the inductance *L*, will be surrounded by a magnetic field.

PHYSICAL NATURE OF A MAGNETIC FIELD

Scientists say that magnetic fields are formed in the ETHER. The ether is pretty much an imaginary substance,

but it does seem to possess certain definite characteristics. First, you'll find it everywhere. Second, to ELECTROMAGNETIC FIELDS, the ether resembles a plastic substance. Don't think that the ether is a tangible substance that you can feel, that you can pick up and toss around. To repeat, to electromagnetic fields, the ether behaves just as a piece of thin sheet steel does in your hands. By using force, the ether can be bent or twisted out of shape. But it will return to its natural position when the force is removed.

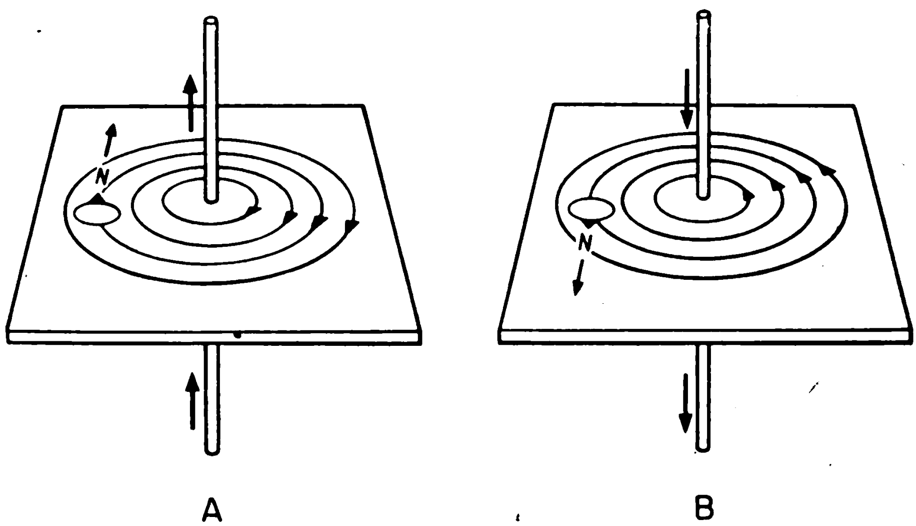


Figure 37.—Magnetic field about a conductor.

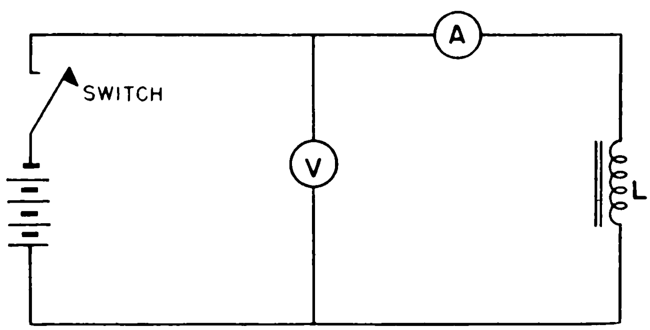


Figure 38.—Magnetic field about a coil.

You have used this principle many times. Remember when you used a ruler to shoot a paper wad at the kid across the schoolroom? You pulled back on one end of the ruler and let go. The ruler jumped forward and launched the paper wad on its way toward your pal's head. But did the ruler stop in its original position? No. Inertia caused it to overjump itself, first in one direction and then in the other for several oscillations, before coming to rest.

The ether surrounding a coil behaves in the same way. FORCE must be used to twist or distort the ether out of shape, and this force is provided by the energy of the current flowing in the circuit. After the field has been created, additional force must be provided by the current to sustain the magnetic field or to hold it in position.

When the current stops flowing, the sustaining force is removed. The magnetic field will COLLAPSE and will feed back to the circuit almost the same amount of energy that was required to create the field.

What about the sustaining force? What happens to this energy? The energy required to sustain the field is lost as HEAT, and therefore cannot return to the circuit as electrical energy.

You can make this basic assumption. Energy is stored in a magnetic field. When the sustaining force is removed, the field will collapse and will return its energy to the circuit.

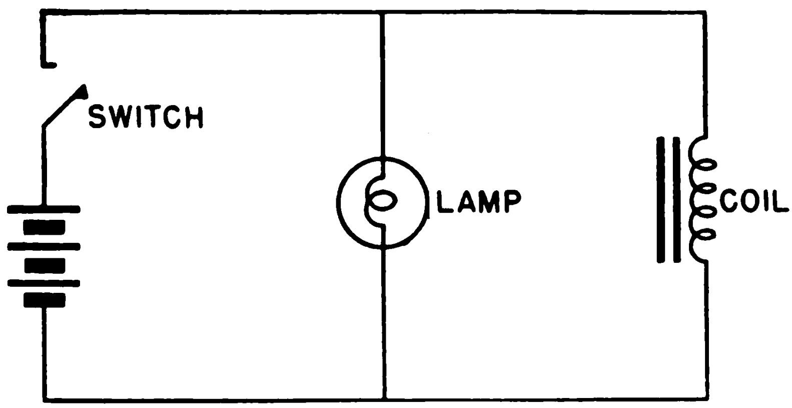


Figure 39.—Collapse of magnetic field causes the lamp to glow.

The ability of a magnetic field to return its energy to the circuit can be demonstrated by the circuit of figure 39. When the switch is closed, current will flow through the lamp and the coil of wire. At the instant the switch is opened, the lamp will flash brightly, indicating that the magnetic field is returning to the circuit the electrical energy that was used to create the field in the first place.

The total energy delivered by the battery in a circuit can be divided into three parts—

FORCE required to produce the magnetic field.

HEAT ENERGY, or loss due to the ohmic resistance.

SUSTAINING FORCE, lost as heat.

REMEMBER—only the energy of the force required to create the magnetic field can be returned to the circuit when the field collapses. The rest is lost.

One more point. Just as the inertia of that ruler caused it to overjump its normal position and vibrate back and forth when its sustaining force was removed, inertia will cause the ether to overjump its natural position and vibrate back and forth.

FUTURE OF THE ETHER THEORY

Some day, a great scientist may show that the present ideas about ether are wrong, or he may prove the present ideas to be correct. Today, this is the best explanation available. It's a good explanation for the action of an inductance in a radio circuit.

SELF-INDUCTION

When a wire moves across a magnetic field, an emf is induced and a current flows in the conductor. This is the principle of INDUCTION. But if the wire is moving PARALLEL to the field, no emf will be developed.

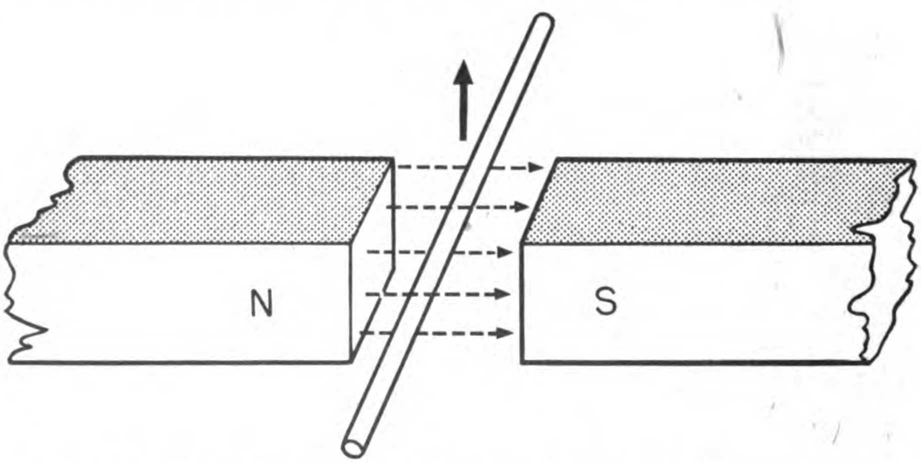


Figure 40.—A current will flow when a conductor cuts a magnetic field.

In figure 40, the conductor is moving through the field of a permanent magnet. When this happens, part of the MAGNETIC energy of the field is changed into ELECTRICAL energy.

But now reverse the situation. Let the conductor stand still, but move the field. Induction will still take place, just as it did with the moving conductor and stationary field.

If BOTH the field and conductor are stationary, no induction will take place.

To have induction, you must have relative motion between the field and conductor.

MOVING ELECTROMAGNETIC FIELDS

In radio, all inductors, such as coils, transformers, and other wires, are fixed. So you'll have to make the FIELDS MOVE if you want induction.

A conductor carrying a steady d.c. is surrounded by a stationary field. When the d.c. is INCREASING in its rate of flow, the field is EXPANDING. When the d.c. is DECREASING, the field is COLLAPSING. So, if the d.c. is either increasing or decreasing in rate of flow, induction can take place.

An a.c. is constantly changing in MAGNITUDE and is periodically reversing its direction of flow. Thus the field produced by an a.c. is constantly in motion. Hence, induction is possible in any circuit carrying a.c.

SELF-INDUCTION

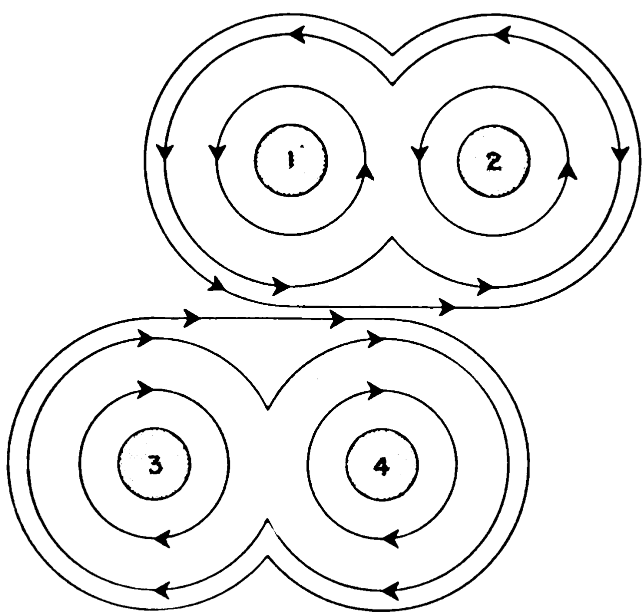


Figure 41.—Self-Induction.

Figure 41 is a cross-section view of a coil. Notice that each turn is close enough to the adjacent turns to permit the field of each turn to cut across the other turns. If this coil is carrying a.c., a CONSTANTLY MOVING magnetic field will be set up. The coil has stationary conductors

and a moving-field—therefore induction will take place.

The field of turn 1 cuts across turn 2. Therefore, a voltage will be induced in turn 2. And this same thing is true of each turn in the coil. Each turn will induce a voltage in each other turn that is within its magnetic field.

The creation of induced voltages in a coil by linkage of the individual magnetic fields is SELF-INDUCTION.

MUTUAL INDUCTANCE

When two coils are placed close to each other so that the magnetic field of one is linked to the turns of the other, the coils are INDUCTIVELY COUPLED.

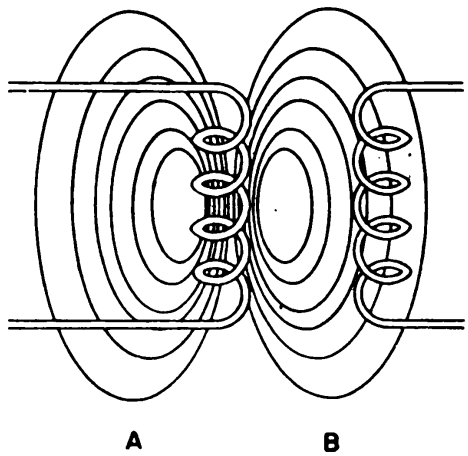


Figure 42.—Mutual inductance.

An a.c. is flowing in the coil of figure 42*A*. The moving field of this coil cuts across the windings of coil 42*B*, and creates an induced voltage. This principle of mutual induction explains the action of a transformer.

Coils placed close together have a higher degree of linkage than coils that are farther apart. When the greatest transfer of energy from one coil to the other is obtained, the coupling is said to be MAXIMUM. The ratio of the actual coupling between the coils to the maximum possible coupling is the COEFFICIENT OF COUPLING.

LENZ'S LAW

What happens to the induced voltage? If the applied voltage is INCREASING, the induced voltage will try to prevent the applied voltage from increasing any further. The opposition of the induced voltage will RETARD the flow of current. But if the applied voltage is DECREASING,

the induced voltage will tend to MAINTAIN the flow of current in the original direction.

This principle of self-induction may be stated in this manner—the induced voltage tends to oppose any changes in the circuit condition. This is LENZ'S LAW.

The ability of a coil to induce a voltage in itself is SELF-INDUCTION, and is one of the most frequently used principles in radio.

FACTORS DETERMINING THE INDUCTANCE OF A COIL

The inductance of a coil is a physical feature of a coil, just as the amount of inertia of a fly wheel is dependent upon the size and weight of the wheel.

The inductance of a coil is determined by the number of turns, the distance between the turns, and the type of core used.

If the turns of a coil are close together, each will be able to link its field with the fields of a greater number of turns, and the inductance will be greater than for a coil with fewer turns spaced further apart.

The inductance of a coil with an air core can be found by using this formula—

$$L = \frac{0.2\, A^2\, N^2}{3A + 9B + 10C}$$

Where—

L is the INDUCTANCE, in microhenries,
A is the AVERAGE DIAMETER of the coil, in inches,
B is the LENGTH of the coil, in inches,
C is the radial DEPTH of the coil, in inches
N is the number of TURNS of wire.

If you wish to calculate the number of turns of single layer wire that are required for a given value of inductance, you may use the formula—

$$N = \sqrt{\frac{3A + 9B}{0.2A^2} \times L}$$

Do not spend any time memorizing these formulas. About the only time that you will need to make such calculations is when you are going to improvise some piece of equipment. And then you can refer to this text for the information.

UNITS OF INDUCTANCE

The unit of inductance is the HENRY. It expresses the relationship between the current flowing and the magnitude of the emf induced. Here's the usual definition for a henry—

> A coil of wire has an inductance of one henry when a change of one ampere per second will cause an emf of one volt to be set up within the coil.

A coil with a current change of 2 amperes a second and induces an emf of 2 volts. It has an inductance of $2 \times 2 = 4$ henries.

If a coil has a current change of 0.005 amperes, a second and induces an emf of 10 volts. It has an inductance of $10 \times 0.005 = 0.05$ henries, or, 10×5 or $= 50$ millihenries.

Inductances used with audio frequencies have iron cores, and may have an inductance as great as 30 henries. Those used with high-frequency r-f will have an inductance as small as a few microhenries.

CHAPTER 6

INDUCTIVE REACTANCE

WHAT IS IT?

You read in BASIC ELECTRICITY that the opposition to the flow of current in an a-c circuit is a combination of the RESISTANCE of the conductor and the OPPOSITION of the self-induced voltage. The opposition created by induction is inductive reactance.

Since the current flowing through an inductive circuit must also overcome the circuit resistance, the total opposition to the flow of current will be the sum of the RESISTANCE and the REACTANCE. Together these two oppositions form the IMPEDANCE of the circuit.

The symbol for inductive reactance is X_L. Impedance is designated by the letter Z.

WHAT DETERMINES REACTANCE?

Two factors determine the reactance of the coil—the INDUCTANCE of the coil and the FREQUENCY of the current. These two factors with the constant 2π (the angular rotation of one complete cycle of a.c.) form the equation for finding the inductive reactance X_L of the coil—

$$X_L = 2\pi\, FL, \text{ in ohms.}$$

Where—

F is the FREQUENCY, in cycles per second,
L is the INDUCTANCE, in henries.

From this equation, you see that the inductive reactance is dependent on the frequency of the current through the inductor and the inductance of the coil.

Example: If a coil has an inductance of 0.1 henry and is carrying a 100-cycle current, the reactance of the coil will be—

$$X_L = 2 \times 3.14 \times 100 \times 0.1 = 62.8 \text{ ohms.}$$

The same coil carrying a current of 1,000,000 cycles, will have a reactance of—

$$X_L = 2 \times 3.14 \times 1{,}000{,}000 \times 0.1 = 628{,}000 \text{ ohms.}$$

Remember that the reactance of the coil increases as the frequency increases.

HOW MUCH IMPEDANCE?

The impedance of a coil can be found by constructing a parallelogram that is proportional to the reactance and resistance.

Use the coil with an inductance of 0.1 henry, a resistance of 50 ohms, and carrying a 100-cycle current as an example.

First, find the reactance. For this coil and frequency, you already know that the reactance is 62.8 ohms.

Next lay out two lines perpendicular to each other, as shown in figure 43.

Now pick a convenient scale. In this case, with an X_L of 62.8 ohms, and an R of 50 ohms, a scale of 20 ohms per inch is good.

In figure 43, the leg for X_L is laid off on the Y-Y' axis. Since X_L is 62.8 ohms, Y-Y' will be—

$$\frac{62.8}{20} = 3\tfrac{1}{8} \text{ inches}$$

The resistance R is laid off on the X-X' axis. With a resistance of 50 ohms, this line will be—

$$\frac{50}{20} = 2\tfrac{1}{2} \text{ inches}$$

Now look at figure 44.

Draw a line through point X parallel to Y–Y'. Next, draw a line through point Y parallel to line X–X'. These two lines intersect at point A.

Draw a diagonal from point A to point X'-Y'. The length of this line represents the IMPEDANCE of the coil, Measure it. It is 4 inches long. Since 1 inch equals 20 ohms, the impedance will be—$Z = 20 \times 4 = 80$ ohms.

CURRENT FLOWING IN A REACTIVE CIRCUIT

How about the current flowing in a reactive circuit? Since the opposition to the flow of current is the TOTAL

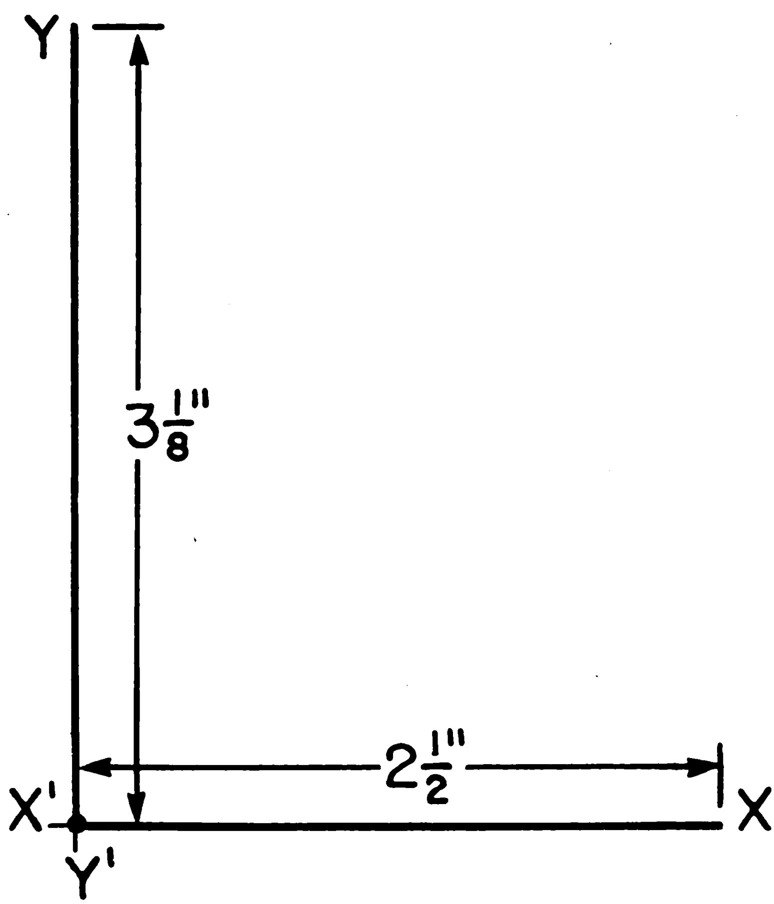


Figure 43.—The two legs of the impedance rectangle.

impedance, Ohm's law will become—

$$I = \frac{E}{Z}$$

If the inductive circuit in the example just completed has an applied potential of 120 volts a.c., the current flowing will be—

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$$I = \frac{120}{80} = 1\frac{1}{2} \text{ amperes.}$$

PHASE ANGLE OF I AND E IN AN INDUCTIVE CIRCUIT

In an inductive circuit, the current tags along or lags behind the voltage. If you could somehow provide an inductive circuit without resistance R, the current would lag the voltage by 90 degrees. But since every circuit has

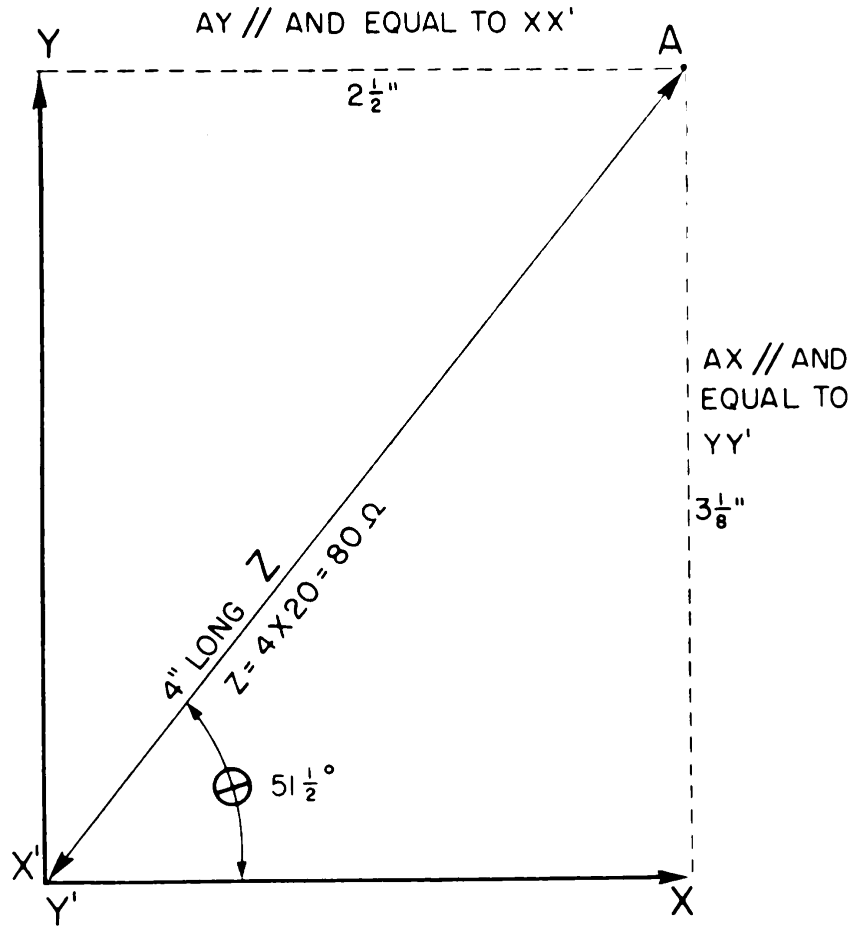


Figure 44.—Completion of the impedance rectangle.

some resistance, the angle of lag is ALWAYS less than 90 degrees.

Look back at figure 44. The angle of lag is indicated by angle θ. If you measure this angle with a protractor, you will find it to be about $51\frac{1}{2}$ degrees.

In figure 45, the angle of lag in a pure inductive circuit is represented by the upper curves. The phase relationship of the current and voltage for the problem you've

just completed is shown by the lower set of curves. The larger the resistance becomes in comparison to the reactance, the smaller the angle of lag becomes.

WHERE YOU WILL USE YOUR KNOWLEDGE

Before they can design electronic equipment, electrical and radio engineers must know inductive reactance, phase angles, and all the related subjects. But you, the electronic technician 3/c, need to know only the MEANING

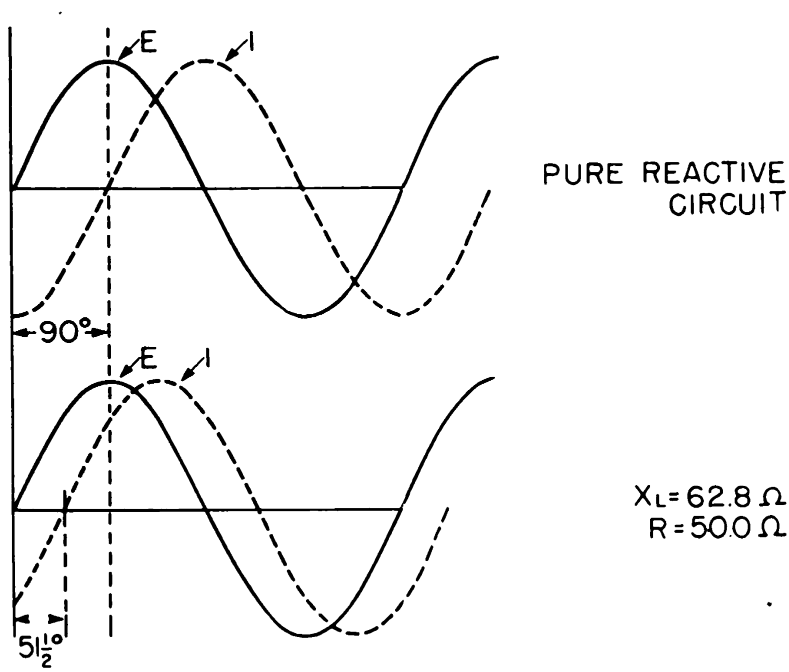
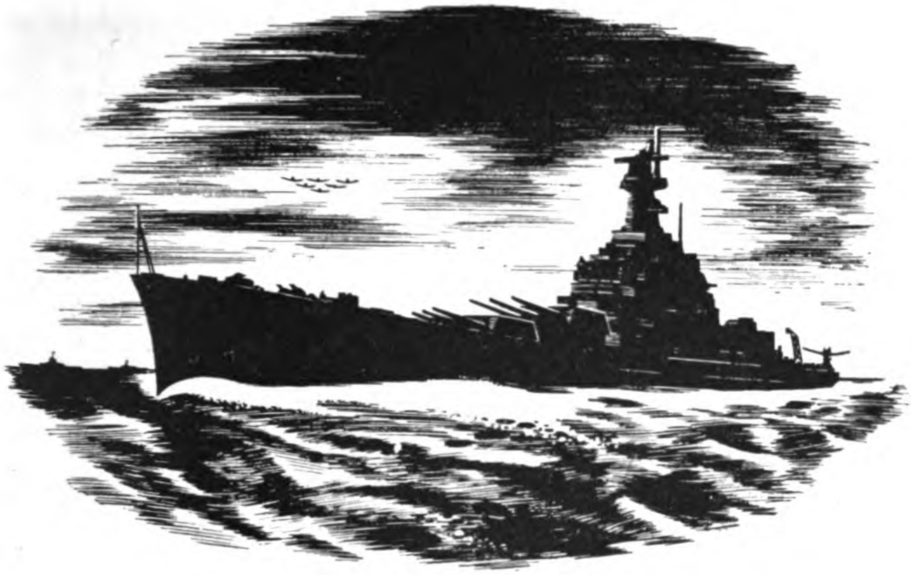


Figure 45.—Phase relationship I and E in an inductive circuit.

OF reactance, impedance, and phase angle, and be able to work simple problems.

You must know the effect that an INDUCTANCE has upon the flow of a.c. in a circuit. Then you can combine inductance with the effect of a condenser to produce RESONANCE.



CHAPTER 7

INDUCTANCES USED IN RADIO

THERE ARE MANY KINDS

This chapter is a discussion of inductances used in radio circuits. It contains examples representative of the kinds you will find used most frequently.

Actually, the shapes and sizes of inductances found in radio and radar equipment is as varied as women's hats on Easter morn. Some are small and cute, and others look more like a bird nest after a rain storm.

Some inductances are very difficult to recognize because they are encased in layers of wax, or hidden inside metal shields. Others have identical external appearance, but entirely different electrical characteristics. As an example of this, the audio frequency choke in figure 46, looks much like the audio frequency transformer in figure 49, but their electrical duties are very different.

Inductances with single windings are usually called coils, while those with a primary and one or more secondary windings are transformers. Most of the inductances used with r-f are called coils regardless of whether they have one or more secondary windings.

CHOKE COILS

The inductances used in radio circuits vary in sizes and shapes. The large choke coil in figure 46 is used in the filter circuits of power supplies.

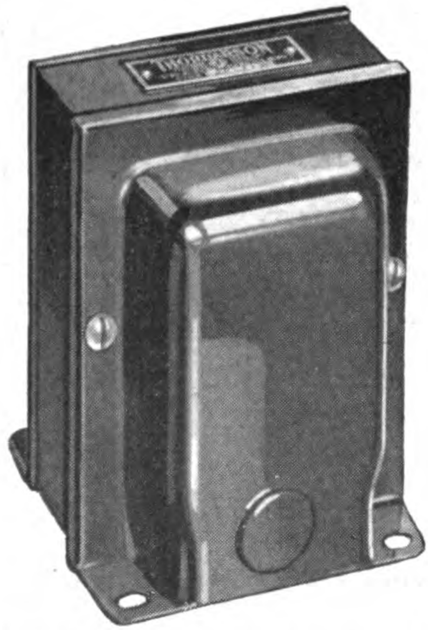


Figure 46.—Audio-frequency chokes used in radio.

It has an IRON CORE to increase its inductance. Chokes of this type have inductances ranging between 10 and 30 henries.

Figure 47.—Radio-frequency choke coil.

The coil in figure 47 is a radio-frequency choke. These choke coils are used to prevent the r.f. from getting into the power supplies and the audio frequency circuits. The inductances of these coils range between a few microhenries and several hundred millihenries.

There are a variety of windings used in making choke coils, but in general they closely resemble a TRANSFORMER with only ONE winding instead of a primary and secondary.

LUMPED AND DISTRIBUTED INDUCTANCE

The choke coils in figures 47 and 48 are called LUMPED INDUCTANCES. This means that practically ALL the inductance is concentrated or LUMPED in a small unit.

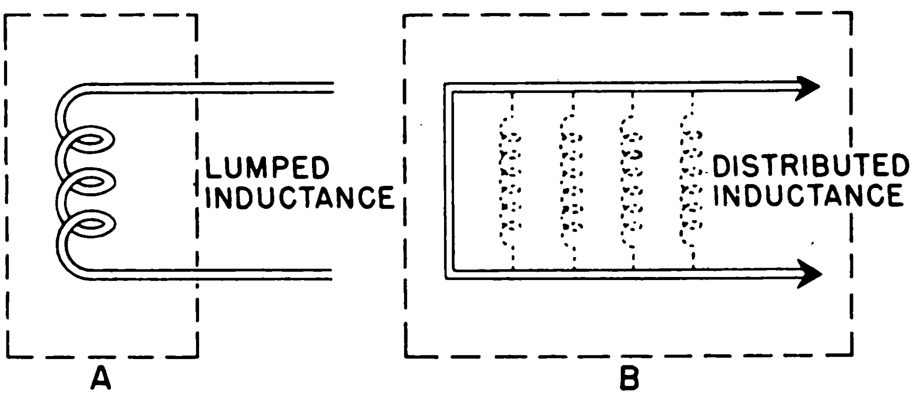


Figure 48.—"Lumped" and distributed inductance.

Figure 48*A* illustrates the meaning of lumped inductance. But what about two straight wires parallel to each other? They too are surrounded by magnetic fields. When carrying a current, and induction will take place between the wires.

Here is the difference. Instead of being concentrated in a small unit, the largest part of the inductance is distributed throughout the length of the wires. If the wires are close together, the inductance is greater. Moving the wires apart decreases the inductance.

Wires that are PARALLEL to each other have a greater inductance than those that are placed at RIGHT ANGLES to each other. Therefore, in radio circuits you keep this unwanted inductance to a minimum by placing the lead wires at right angles to each other. This is an important point to keep in mind but one that is frequently overlooked.

TRANSFORMERS

Radio circuits use two general types of transformers—the low frequency audio transformers with IRON cores, and r-f transformers with AIR cores.

Because of the huge energy losses in the iron, iron cores are NOT generally used with r-f transformers. If iron is used, it is in powdered form in order to reduce hysteresis loss. Here is why. ENERGY is used to create the magnetic field. When the polarity of the transformer is reversed, additional energy is required to DESTROY the original field and cause it to flow in the opposite direction. This energy is wasted in the form of heat. With r.f., the field is reversed so often that the heat produced would burn out the transformer.

Figure 49 shows a common type of audio-frequency transformer used to couple two stages of an amplifier.

Figure 49.—Audio-frequency transformers.

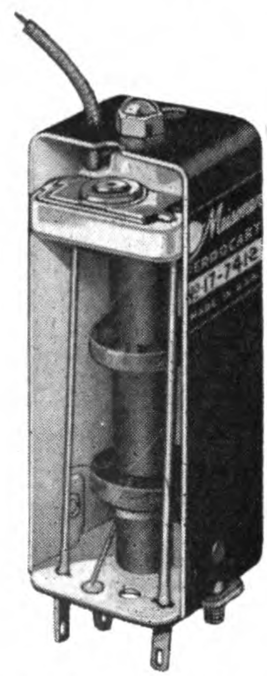


Figure 50.—Radio-frequency transformers.

Figure 50 shows a type of transformer used with r.f. These transformers are called COILS. The coil has a tuned PRIMARY and a tuned SECONDARY, and is used in the intermediate frequency stage of a superheterodyne receiver. This coil and its tuning will be discussed in the chapter on the superheterodyne receivers. Figure 51 shows a type of air-core inductor used with transmitters.

TRANSFORMER VOLTAGES

The relationship of voltages in the primary and secondary is of major importance to the radio technician. One transformer is often required to deliver several different voltages at the same time.

You remember that the voltage in the secondary bears the same relationship to the primary voltage as the number of the turns in the secondary bears to the turns in the primary. Thus, if 100 volts is impressed across a primary of 200 turns, the voltage in the secondary of 400 turns will be 200 volts, or $1:2 = 2:4$.

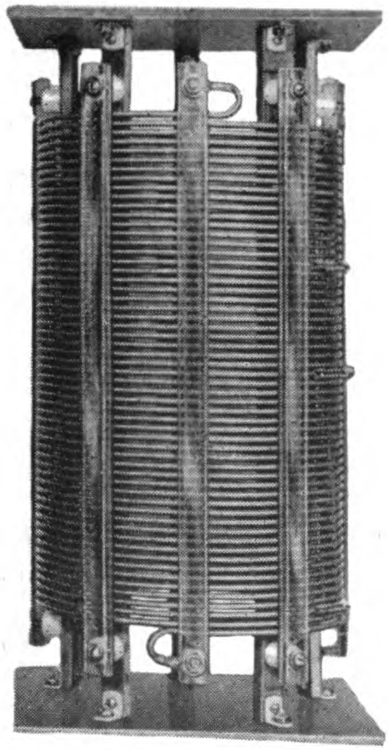


Figure 51.—Air core inductor used with transmitters.

POWER TRANSFORMERS

Transformers used to supply the voltages to motors, lighting circuits, power supplies, and similar devices, are usually classified as POWER TRANSFORMERS. They may be either step-up or step-down, designed to deliver a high voltage with a low current, or a low voltage with a high current.

As far as you are concerned, the most important part of your work with transformers is to learn how to CON-

NECT THEM CORRECTLY so that they will deliver the proper voltages without being overloaded and burning out.

Figure 52 shows a typical power transformer. Some power-supply transformers have three or four separate windings, in order to supply three or four different voltages. Many windings have center-tapped secondaries. This permits grounding to the chassis to reduce a-c hum. If the high-voltage center tap is grounded, the voltage across the two outside terminals is twice as large as the voltage from either outside tap to the center tap.

TRANSFORMER POLARITY

Ordinarily you do not think of a transformer as having polarity, but it does. It has a HIGH-VOLTAGE and a LOW-VOLTAGE side. One terminal of the high-voltage side and one terminal of the low-voltage side are at MAXIMUM POSITIVE at the same instant. On the next half-alternation, these same two terminals will be MAXIMUM NEGATIVE. These two terminals are said to have LIKE POLARITY.

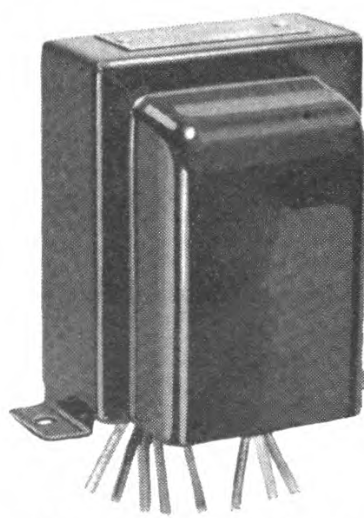


Figure 52.—Power-supply transformer.

Several systems are used to mark the polarity of a transformer. One of the more common is to use the letter H to designate the high-voltage side, and the letter X to indicate the low-voltage side. Do not be confused into thinking that H always indicates the secondary—the high-voltage side may be EITHER the secondary or the primary. Transformers can be either step-up or step-down. In figure 53A, the high side H is the PRIMARY of

the step-down transformer, while in figure 53*B* the high side is the SECONDARY of a step-up transformer.

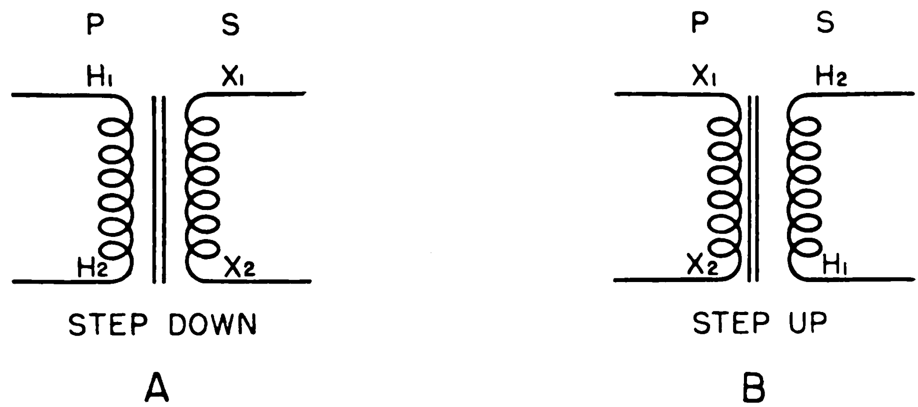


Figure 53.—Transformer polarity.

Notice also in figure 53 that the polarity markings H and X have subscripts 1 and 2. This means that H_1 and X_1 are both maximum positive or negative at the same instant. Likewise, H_2 and X_2 are at the same polarity at the same instant.

TRANSFORMER POLARITY IS IMPORTANT

If a transformer is used by itself, the polarity is not too important. However, if you wish to connect two transformers in series or in parallel, the terminals must be connected together correctly or the transformer will burn out.

You want to connect the two primaries of a transformer in series. If they are connected backwards, as in

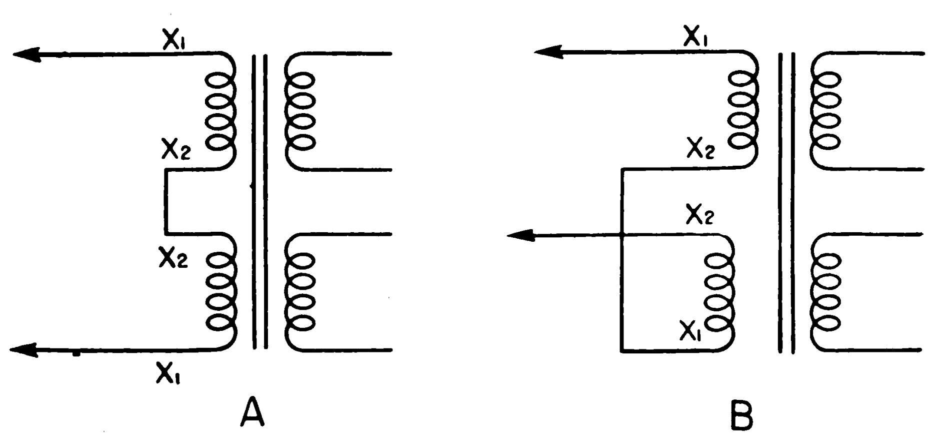


Figure 54.—Incorrect and correct series connections for primary windings.

figure 54*A*, the flux of one winding will cancel the flux of the other, causing the X_L to become almost zero. This

leaves only the low d-c resistance of the windings to oppose the flow of current. The result—a burned-out primary.

In figure 54*B*, X_2 is connected to X_1 indicating that like and unlike terminals have been connected together correctly for a series connection.

DETERMINATION OF POLARITY—PHASING-OUT

If the polarity of a transformer is not marked, it will be necessary for you to PHASE-OUT the transformers—determine the polarity—before you can safely connect the two together. This can be done as shown in figure 55.

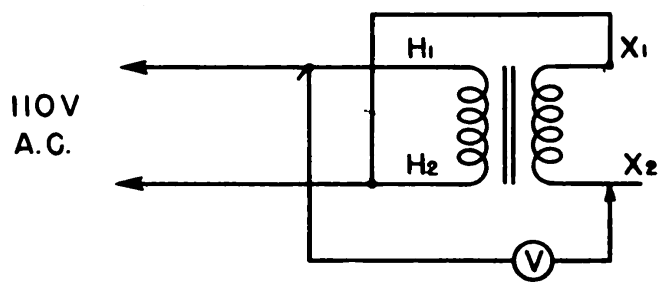


Figure 55.—Determining the polarity of a transformer.

Connect a primary terminal and a secondary terminal as indicated. Next, connect an a-c voltmeter from the free secondary X_2 to the free primary tap H_1. Now connect the primary to an a.c. source of the correct voltage. If the volmeter reads the SUM of the primary and secondary voltages, they are connected in SERIES, meaning that the primary and secondary terminals connected together are of OPPOSITE polarity. If the voltmeter reads the DIFFERENCE between the secondary and primary voltage, the two terminals are of LIKE polarity. Sometimes the first condition is described as ADDITIVE POLARITY, and the second as SUBTRACTIVE POLARITY.

Another method of phasing-out a transformer with two windings on each primary and secondary is shown in figure 56.

Connect two of the primary terminals together, as at H_2-H_1. Connect an ammeter *A* and a resistance *R* in series with a 110-volt line and the primary windings, as shown in the drawing. Turn on the power. If the current flowing in the primary circuit is very SMALL—almost zero—the two terminals are UNLIKE terminals and are connected correctly for a SERIES connection. If the cur-

rent reading is LARGE—approximately equal to 110 volts divided by R of the resistance—two LIKE polarities are connected together and one of the connections must be REVERSED for a series connection.

A similar test is applied to the secondary. Connect two of the terminals together. Place a voltmeter across the other two terminals. If the meter reading is almost zero, the connection is INCORRECT for a series connection—REVERSE one of the leads. If the voltage is large—approximately the applied voltage times the turns ratio—the connection is CORRECT for a series connection.

IN SERIES AND IN PARALLEL

You'll usually connect transformers in series or in parallel in order to achieve a certain advantage not possible with a single transformer. Figure 57 shows two possible arrangements.

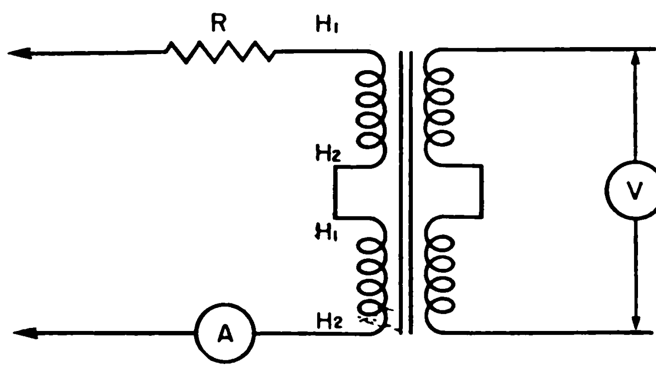


Figure 56.—Phasing-out a transformer.

The first shows how it is possible to get 660 volts from a 220-volt line input by using two 1-to-3, 110-volt transformer. The second shows how 1320 volts can be obtained from a 220-volt line by using two 1-to-3 220-volt transformers. These two examples should suggest other combinations that may be used to obtain a variety of voltages.

THREE-PHASE TRANSFORMERS

So far, only single-phase transformers have been discussed. It is not possible to transform a 3-phase voltage with ONE single-phase transformer, but it is possible to step-up or step-down a 3-phase voltage by using THREE single-phase transformers.

Some specially designed 3-phase transformers have all the windings built into one enclosed case. But the 3-phase

transformer will be discussed here as if it were three separate single-phase transformers.

Two basic connections—STAR and DELTA—are used with 3-phase voltages. Each is shown is figure 58. The primary of the transformer is connected STAR, and the secondary is connected DELTA. Be sure to observe the INDICATED POLARITY.

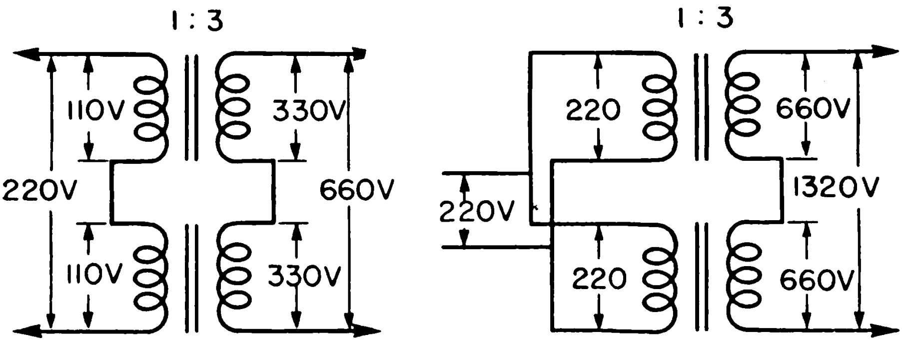


Figure 57.—Transformer connections in series and in parallel.

The primary in figure 58 is connected star and the secondary is delta. It is also possible to have the primary connected delta and the secondary as star. You can also use a delta-delta or a star-star connection depending upon the voltages you wish to obtain. A star arrangement is also described as a *Y*, and a delta as a "Δ" connection. Thus, *Y*-*Y* would be a star PRIMARY and a star secondary, while a Δ-*Y* would be a delta primary and a star secondary.

THREE-PHASE CURRENT AND VOLTAGE

Four terms, "line voltage," "phase voltage," "line current," and "phase current," are used to express the characteristics of a three-phase transformer. The LINE VOLTAGE is the voltage that appears BETWEEN ANY TWO LEADS on the primary or on the secondary. The PHASE VOLTAGE is the voltage that appears ACROSS ANY ONE WINDING. LINE CURRENT is the current that is flowing in any line. PHASE CURRENT is the current flowing through any ONE WINDING.

Before you can fully understand the operation of a 3-phase transformer, you must know the relationships of the current and voltage in both the star and the delta connections. The following table is a summary of the characteristics for the star and delta connection—

Star	Delta
Line I = Phase I	Line I = Phase I = 1.73
Line E = $E \times 1.73$	Phase I = Line $I \div 1.73$
Phase E = Line $E \div 1.73$	Line E = Phase E

For the present, just remember these characteristics. You will soon see how they apply to the two types of connections.

STAR-STAR CONNECTION

The first step in making a STAR-STAR connection is to determine the relative polarity of all the terminals on the three transformers. If the polarities are marked, your job is simple; if not, you must check them yourself.

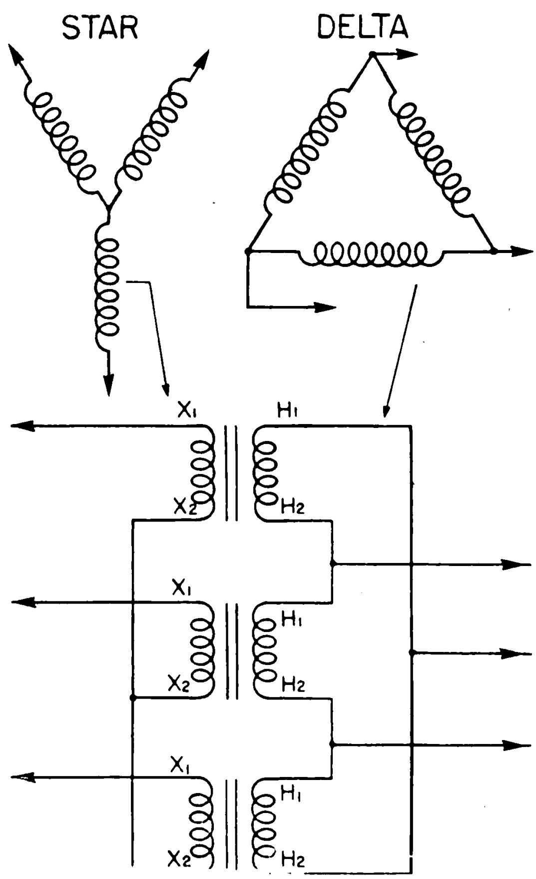


Figure 58.—Star and delta three-phase transformer connections.

Next, connect three PRIMARY terminals of like polarity together. Then connect the three SECONDARY terminals with like polarity, as indicated in figure 59. The three vacant terminals in the primary and in the secondary are the primary and secondary leads to the transformer.

Now, how about the current and voltage relationships? In figure 59, 1-to-2 step-up transformers are indicated. Line potential is 100 volts, and is applied to the primary.

Look back at the characteristics of a star connection. The primary phase voltage is—

$$\text{Line } E \div 1.73 = \text{Phase } E$$

Therefore, the voltage appearing across the primary

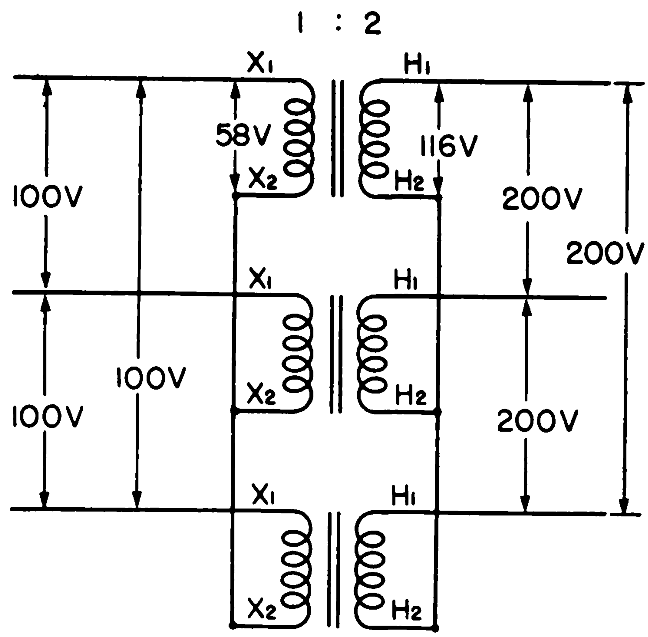


Figure 59.—Star-star connection.

of each transformer is—

$$100 \div 1.73 = 58 \text{ volts.}$$

Since the tranformer is of a 1-to-2 ratio, the potential appearing across the secondaries—the phase voltage—is 116 volts.

The LINE VOLTAGE in the secondary is—

$$\text{Phase } E \times 1.73 = \text{Line } E$$

Thus, the line voltage is—

$$116 \times 1.73 = 200 \text{ volts}$$

Notice that in a star-star connection, the secondary line voltage is equal to—

$$\text{Primary line } E \times \text{turns ratio} = \text{Secondary line } E.$$

For the current in the primary and secondary, since

primary $E \times$ primary $I =$ secondary $E \times$ secondary I the current flowing in the secondary is the INVERSE of the turns ratio times the primary current. Thus, in figure 59, if the maximum safe current in the primary is 10 amperes, the maximum current that can be safely drained from the secondary is $10 \times \frac{1}{2} = 5$ amperes.

DELTA-DELTA CONNECTIONS

The connections of a delta-delta transformer are shown in figure 60. The primary may be connected without checking on the polarity, but the secondary MUST BE PHASED-OUT. Notice that the lead lines are attached to the connections BETWEEN THE WINDINGS in both the primary and the secondary.

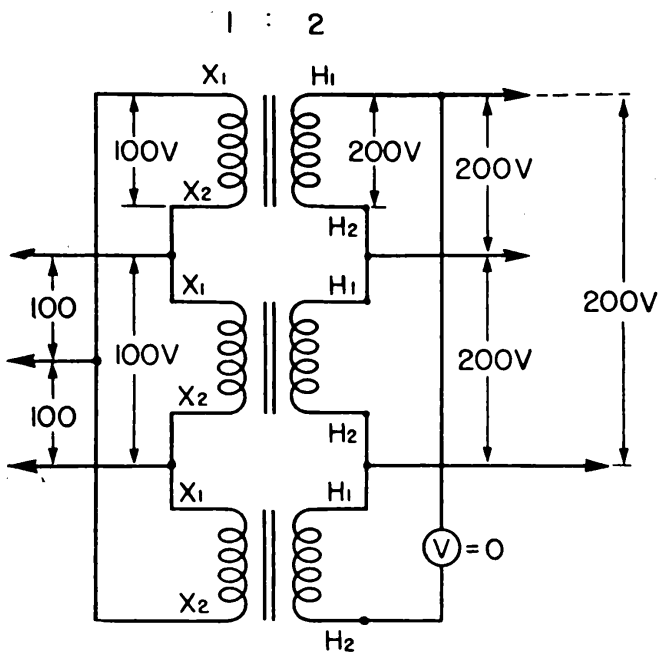


Figure 60.—Delta-delta transformer connection.

Connect two secondary terminals of two of the transformers together. Place a voltmeter across the open leads of these windings. If the meter reads—$E_M =$ primary line $E \times$ turns ratio—the connections are correct. For the circuit of figure 60, this voltage E_M should be $100 \times 2 = 200$ volts.

If the actual voltage E_M is greater than this, the connections are incorrect, and one of the leads must be reversed.

Next, connect a lead of the third transformer to an unattached lead of the other two transformers. Place a volt-

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meter across the two remaining open leads. If the third transformer has been connected correctly, the meter will read ALMOST ZERO. If the reading is LARGER than this, REVERSE the leads of the third transformer.

When a zero reading has been obtained, remove the meter and close the circuit by connecting the two remaining secondary leads together.

Since the PHASE VOLTAGE in a delta connection is the same as the LINE VOLTAGE, the line voltage of a delta secondary will be 200 volts with a 100-volt input to a delta primary, if the ratio is 1-2.

The maximum current in the secondary of a delta-delta connected transformer is the INVERSE of the turns ratio times the maximum primary current, or—

$$\text{Primary line } I \times \frac{1}{\text{Turns ratio}} = \begin{array}{l}\text{Maximum} \\ \text{secondary current.}\end{array}$$

STAR-DELTA TRANSFORMER CIRCUITS

A transformer with a star primary and a delta secondary or with a delta primary and a star secondary has a different relationship between primary-secondary currents and voltages than does a Y-Y or a Δ — Δ connection.

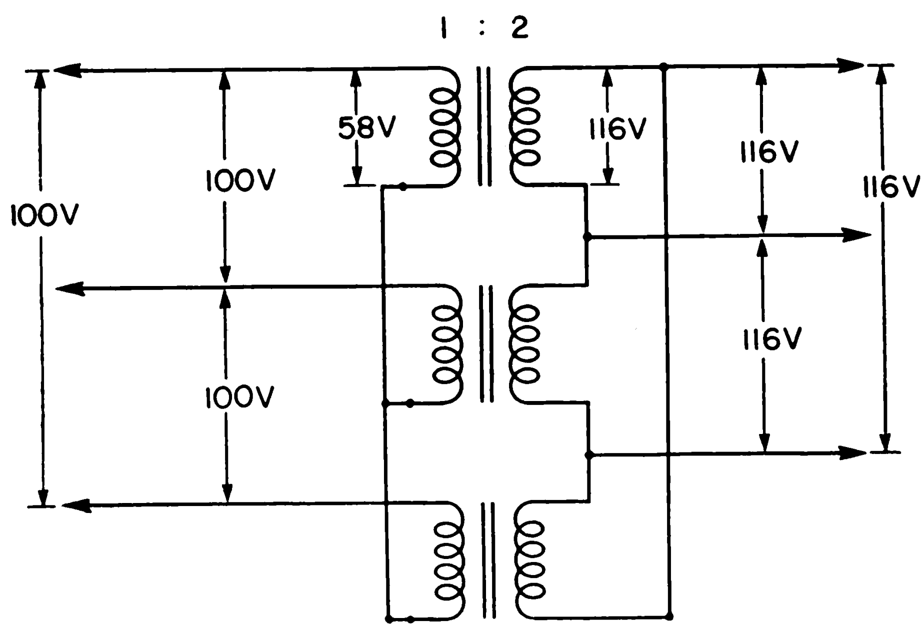


Figure 61.—Star-delta transformer connection.

Figure 61 is a star-delta connection. If the input line potential is 100 volts, the primary phase voltage is—

$$100 \div 1.73 = 58$$

Since the transformer has a 1-to-2 ratio, the secondary phase voltage is—

$$58 \times 2 = 116$$

The secondary is a delta connection with Phase E = Line E. Therefore the secondary line potential is 116 volts.

If the maximum safe primary phase current is 20 amperes, the maximum secondary phase current is—

$$20 \times \tfrac{1}{2} = 10 \text{ amperes}$$

But in a delta connection, Line I = Phase I x 1.73. Then the secondary line current will be—

$$10 \times 1.73 = 17.3 \text{ amperes.}$$

DELTA-STAR TRANSFORMER CONNECTION

A DELTA-STAR transformer is capable of delivering a greatly stepped-up voltage, but with a decrease in the safe maximum secondary line current.

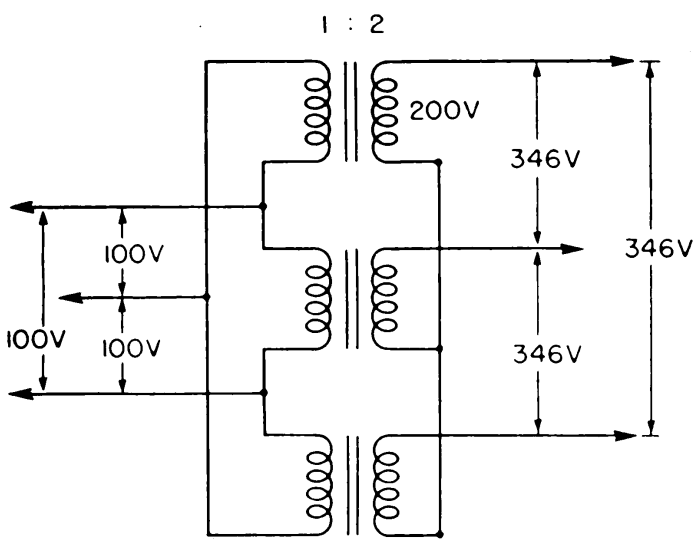


Figure 62.—Delta-star transformer connection.

In figure 62, a LINE POTENTIAL of 100 volts is used. Because the primary is delta, the PHASE VOLTAGE is also 100 volts. With a step-up transformer of 1:2, the SECONDARY PHASE voltage is 200 volts. The secondary line voltage will be—

$$200 \times 1.73 = 346$$

Here you have an increase in voltage from 100 to 346 volts, using only a 1-to-2 transformer. This often proves to be an advantage, because you are able to obtain better than 1-to-3 step-up with a 1-to-2 transformer.

If the maximum safe primary phase current is 20 amperes, the maximum safe secondary phase current will be 10 amperes, but the maximum safe secondary line current will be only—

$$10 \div 1.73 = 5.8 \text{ amperes.}$$

WHICH CONNECTION WILL YOU USE?

Once more, the connection you will use to transform 3-phase voltages will depend upon the line voltage, the volume of current, and the operating voltages of the load. When you are going to make a connection, use the one that will produce the best results for your needs.

SINGLE-PHASE VOLTAGE FROM THREE-PHASE LINES

A single-phase voltage can be obtained from any two lines of a three-phase system. Be careful—check the line voltages when you wish to take a single-phase voltage off a 3-phase system. This voltage can easily be more or less than you expect it to be, especially if you do not know the type of transformer connection that is being used. Failure to make this check may result in the improper operation of the gear, or even its destruction.

CHAPTER 8

THE CONDENSER

CONDENSER OR CAPACITATOR?

Easiest way to start a debate at a convention of radio technicians is to get on your feet and say that a condenser isn't a condenser at all—it's a CAPACITATOR! Technically speaking, you'll be right but that won't get you anywhere—you'll still lose the debate. The device has been known as a condenser for years and most radio men like it that way. It's the accepted term.

For instance: If you asked a mate to run down to the shop and get you a VARIABLE CAPACITATOR, he'd think you were talking about some kind of a medieval head-removing machine. To avoid such confusion, a condenser is a condenser as far as this training course is concerned and it shall be referred to as such.

HOW DOES A CONDENSER CHARGE AND DISCHARGE?

You studied the structure of the condenser in the book on BASIC ELECTRICITY. And, you learned that the condenser could be charged to a high voltage. When you placed two ends of an insulated wire across the terminals of a charged condenser, you saw the discharge spark. Since you're a technician, the way a condenser charges and discharges will be of special importance to you.

In figure 63 a condenser is connected across the terminals of a 6-volt battery. When the switch is closed, current electrons will flow out at the negative pole of the battery into the condenser. At the same time, other electrons are flowing out of the opposite side of the condenser and into the battery. The side of the condenser that the electrons entered will have an excess of ELECTRONS, so it will be NEGATIVELY charged. The other side of the condenser loses some electrons, so it will become POSITIVELY charged.

Electrons run into one side of the condenser and force electrons out at the other, and the condenser becomes charged. Could electrons enter one side of the condenser unless other electrons leave the opposite side? No. Unless electrons are able to leave, other electrons cannot enter the other side. To charge a condenser, electrons must be able to flow into one plate of the condenser and shove other electrons out at the other plate.

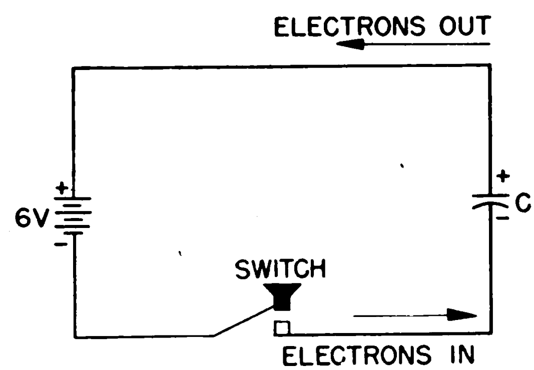


Figure 63.—How a condenser charges.

Electrons will enter and leave the condenser until the condenser is fully charged. When is a condenser "fully charged"? When the voltage ACROSS THE CONDENSER is equal to the APPLIED voltage. In the circuit of figure 63, this condenser will be fully charged when the voltage across the condenser is 6 volts.

But replace the 6-volt battery with a 100-volt battery. The condenser will then be fully charged when the voltage across the condenser reaches 100 volts.

A CONDENSER CONDUCTS A.C.

One of the most useful characteristics of a condenser is its ability to conduct a.c., and at the same time to block completely the flow of d.c. through a circuit. Remember

the construction of a condenser? It is composed of two plates separated by an INSULATOR. The condenser acts as an insulator or an open circuit, and no d.c. can flow unless it is pulsating d.c.

How can the condenser conduct a.c.? Remember that a condenser can charge and discharge when the polarity of the current is reversed. Look at figure 64, in which a condenser has been connected across the source of a.c.

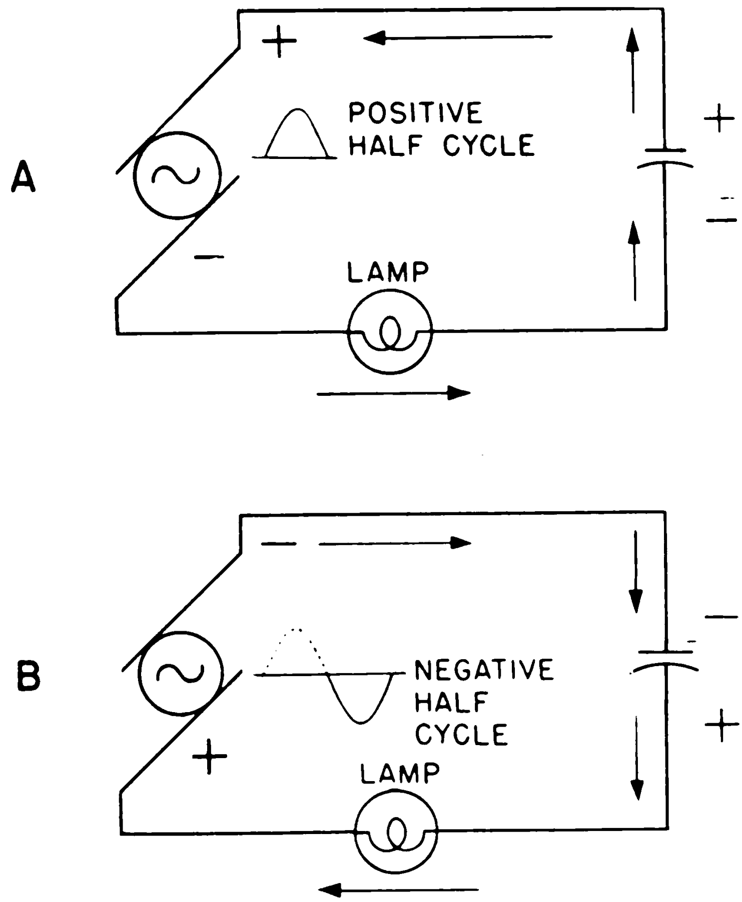


Figure 64.—How a condenser conducts a.c.

In figure 64*A*, the lower side of the generator is negative. Electrons will flow out of this side through the lamp and into the lower plate of the condenser. At the same time, other electrons are flowing out of the top plate of the condenser and back to the positive side of the generator.

When the cycle reverses itself, the direction of the current will also reverse. Electrons will now flow to the top plate of the condenser and out at the bottom. The condenser first DISCHARGES, and then RECHARGES in the opposite direction. When the cycle reverses again, the con-

denser will discharge, then charge in the opposite direction. While all this charging and discharging is going on, the lamp is lighted, showing you that current is being carried through the circuit.

But—ELECTRONS DO NOT GO THROUGH THE CONDENSER. They merely flow in at one side and accumulate on one plate, while other electrons are leaving the opposite plate. When the cycle reverses, the electrons flow in the opposite direction.

A CONDENSER BLOCKS THE FLOW OF D.C.

When a condenser is placed in a d-c circuit, electrons will run in at one side and out at the other. But after the condenser has once become charged, NO MORE current will flow. Since a condenser will readily conduct a.c., but will stop d.c., it is a good device for separating the two voltages.

REACTANCE

Like any other electrical device, a condenser offers opposition to the flow of current. Since the condenser acts as an open circuit to d.c., the opposition to the movement is not resistance, but is REACTANCE.

The reactance of a condenser depends upon its CAPACITY and the FREQUENCY of the a.c. it is carrying. In each case, the higher the frequency and the larger the capacity, the LOWER the reactance will be. The equation for finding the reactance of the condenser is—

$$X_c = \frac{1}{2\pi fC} \text{ohms}$$

Where 2π is the angular rotation for a complete cycle, and

f is frequency, in cycles

C is capacity, in farads.

Notice that both f and C are in the denominator of the equation. So, as frequency and capacity INCREASE, the reactance will DECREASE. This is important in radio. Frequently a single circuit will be carrying a wide range of frequencies. Often you'll want to drain or filter off the high-frequency currents, and leave only the lower frequencies. The TONE CONTROL in your radio does this job.

To understand how a condenser does this filtering, look at the following table.

If the capacity of condenser = 0.1 mf.

A FREQUENCY of	gives a REACTANCE of
100 cycles	15,900 Ω
1,000 cycles	1,590 Ω
2,000 cycles	795 Ω
4,000 cycles	397 Ω
8,000 cycles	198 Ω
10,000 cycles	159 Ω
1,000,000 cycles	1.59 Ω

Notice that the reactance of the condenser at the frequency of 100 cycles is 15,900 ohms. This 100-cycle frequency is down in the musical bass. At a frequency of 8,000 cycles, the reactance is 198-ohms, and at 10,000 cycles, the reactance is 159 ohms. The higher frequencies, 8,000 and 10,000 cycles, are notes of the high-pitched treble instruments.

CONDENSER SEPARATES H–F AND L–F CURRENTS

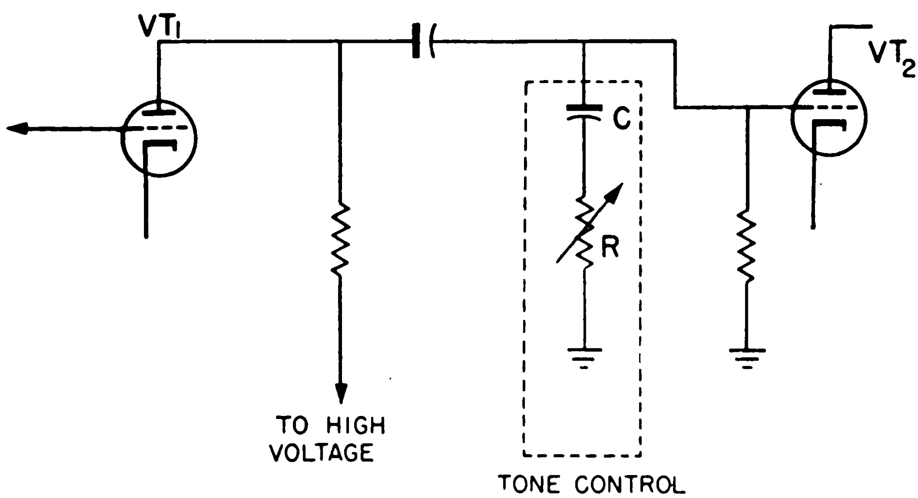


Figure 65.—Use of a condenser as a tone control.

The portion of figure 65 included inside the dashed lines is a TONE CONTROL. The upper end of the condenser is connected to a circuit carrying both high and low frequencies. The lower end of the condenser is connected to a rheostat *R*. The rheostat controls the resistance between the condenser and ground.

The condenser will offer a HIGH REACTANCE to the low frequencies, so they cannot escape to ground. The re-

actance of the condenser to the frequencies near 8,000 cycles is very low, and they can easily escape to ground.

The filtering-off of the high-frequency notes increases the PERCENTAGE of the bass notes remaining. This gives the effect of INCREASING the strength of the lower notes. But actually you are only draining off the high-pitched treble and leaving the bass notes as they were.

Notice in the table above that the reactance of a 0.1-mf. condenser for a frequency of 1,000,000 cycles is only a little more than 1½ ohms. A reactance that small is equivalent to a SHORT CIRCUIT.

One of the most common uses of a condenser in radio circuits is to conduct a high-frequency current to another part of a circuit, and at the same time offer a HIGH REACTANCE to low-frequency currents.

Many times a condenser will be connected directly between a line carrying audio and radio frequencies. The RADIO frequencies will escape by being by-passed to ground, but the AUDIO frequencies will be carried on to the next stage of the radio.

IMPEDANCE IN A CAPACITIVE CIRCUIT

You'll always be running into resistance. Any circuit that contains a condenser also has resistance. As you already know, impedance is the combined opposition of X_C and R to the flow of current.

If a capacitive circuit were free of resistance, the current would lead the voltage by 90 degrees. But because every circuit does have resistance, the angle of lead is always LESS than 90 degrees.

You find the IMPEDANCE and the angle of LEAD of a CAPACITIVE circuit in the same way as you found the impedance and angle of LAG in an INDUCTIVE circuit. Here's an example—

A capacitive circuit has a resistance of 10 ohms. The condenser has a capacity of 0.1 mf. If the frequency of the current is 100,000 cycles, find the IMPEDANCE of the circuit and the ANGLE of LEAD for the current.

First, solve for the reactance of the condenser.

$$X_C = \frac{1}{2 \times 100{,}000 \times 0.1 \times 10^{-6}}$$

$$X_C = 16 \text{ ohms}$$

The next step—solve for the impedance and the angle of lead by using a VECTOR DIAGRAM.

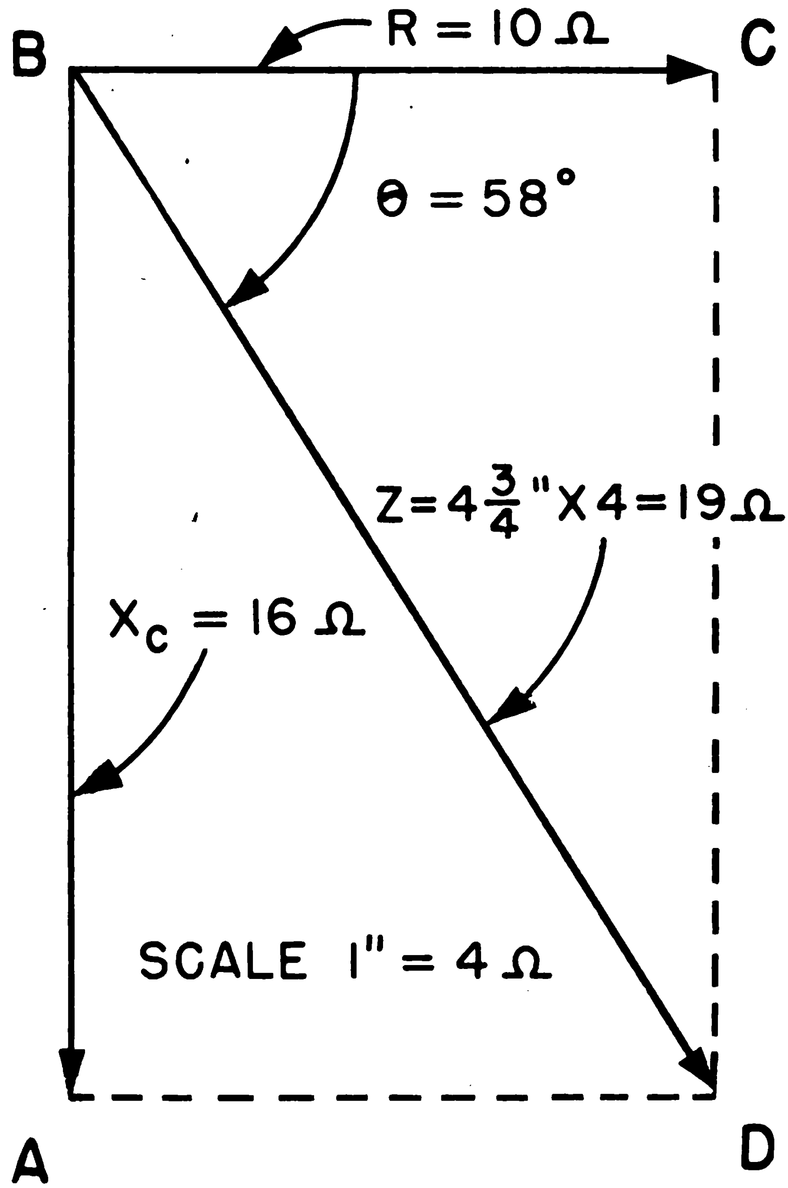


Figure 66.—Vector diagram showing relationship of *R*, Xc, and Z.

Figure 66 is the VECTOR solution of the problem. Notice that the vector *BA* of X_C extends in the opposite direction to the vector *BC* for X_L. That's right, because the current in an inductor LAGS, while the current in a condenser LEADS the voltage. Thus the vectors for X_C and X_L must point in opposite direction.

The impedance is represented by the diagonal *BD*. This line is approximately 4¾ inches long. Using the scale,

1″ equals 4 ohms, the impedance will be—

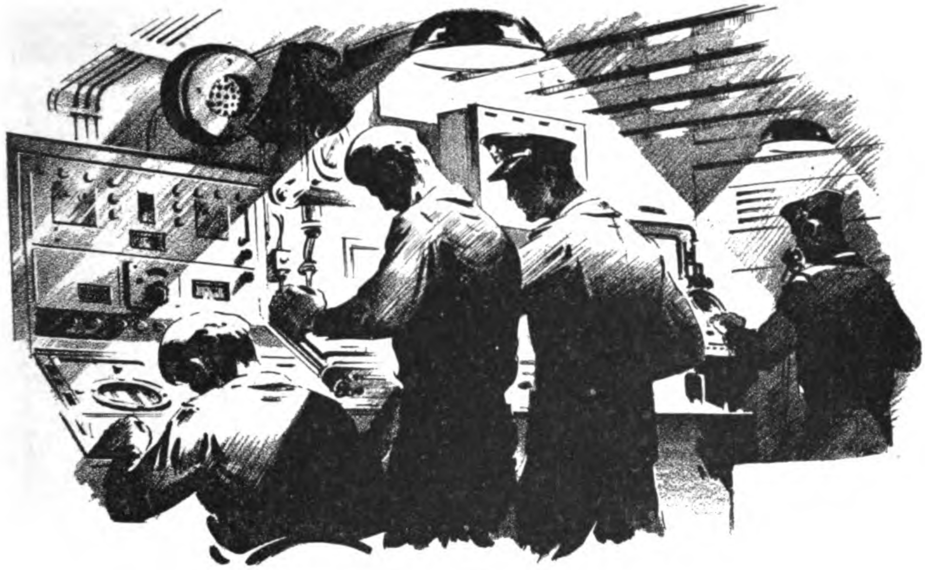
$$Z = 4\tfrac{3}{4} \times 4$$

$$Z = 19 \text{ ohms}$$

The PHASE ANGLE is angle ABC. By measuring with a protractor, you find it to be 58 degrees.

CURRENT FLOWING IN A CAPACITIVE CIRCUIT

Since a capacitive circuit contains BOTH reactance and resistance, the current flowing in the circuit is inversely proportional to the impedance of the circuit. Thus Ohm's law for a circuit containing a condenser and carrying an a.c. is $I = \frac{E}{Z}$ just as it is in an inductive circuit.



CHAPTER 9

RADIO CONDENSERS

VARIETY OF SIZES AND SHAPES

Rest your eyes for a few minutes and collect a half dozen or so condensers from around the shop. Pick out the different types and line them up side by side on the workbench. Your row of condensers will bear a striking resemblance to the next to last row of chorus girls in a honky-tonk night club. Each will be a different size and each will have a different shape.

Condensers are manufactured in a variety of sizes and shapes to fit specific needs in radio. You'll run across a lot of them in your work as a radio technician but the four specific types mentioned here are representative of most of those that you'll have to work with. First in the line is the variable condenser. It is followed closely by the fixed variable condenser, the paper condensers, the electrolytic and the mica condensers.

VARIABLE CONDENSERS

In figure 67 you see a variable condenser. The dielectric is AIR, and the CAPACITY of the condenser is changed by rotating one set of plates. This condenser is designed to be used in transmitters.

The size of the condenser depends upon the FREQUENCY

BAND at which the radio is to be operated. At high frequency, a few small plates will be used and the distance between places will be large. For low frequencies, the plates will be larger and closer together.

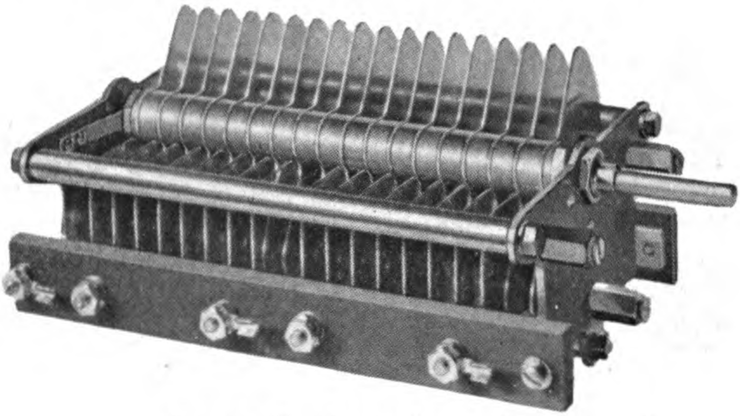


Figure 67.—Variable condenser.

The capacity of this condenser can be reduced by removing some of the plates or by using smaller plates. To increase the capacity of this type of condenser, add plates or use larger plates.

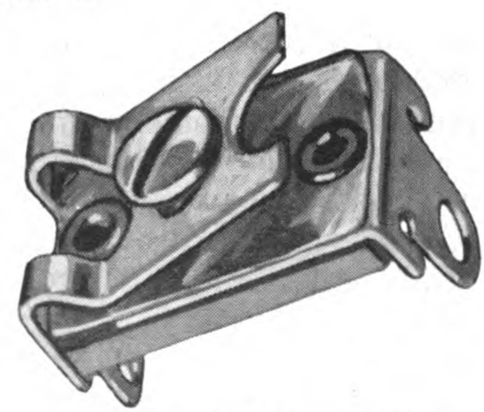


Figure 68.—Padder condenser.

Figure 68 illustrates a FIXED variable condenser. This type has a slotted screw holding the plates together. The plates are not perfectly flat, but are a little warped or bowed, and are separated by pieces of mica. By tightening the screw, the plates are forced closer together, and the capacity of the condenser is INCREASED.

These condensers are used with FIXED TUNED circuits, such as intermediate frequency circuits of the superheterodyne. They are often used in parallel with variable condensers to correct any variations between condensers during manufacture. They are sometimes called PADDERS

or TRIMMERS, depending on how they are used in the radio circuit. This type of application is given in figure 69.

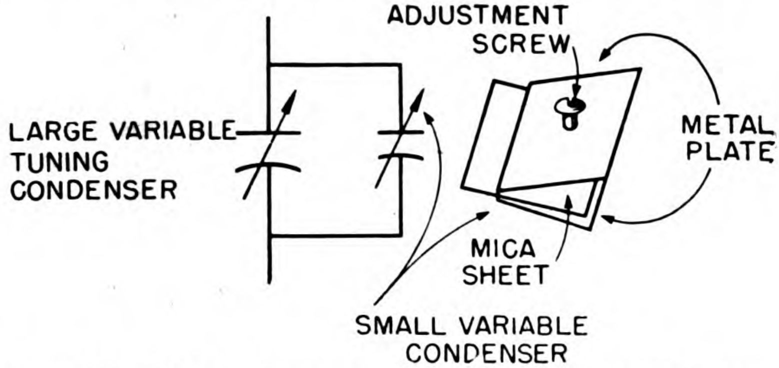


Figure 69.—Use of trimmers in parallel with tuning condensers.

PAPER CONDENSERS

The condenser in figure 70 is a PAPER CONDENSER. The plates are metal foil, and the dielectric separator is usually a piece of wax paper. The plates and the dielectric are rolled to form a cartridge. The whole unit is then encased in another paper container and sealed to prevent moisture from getting in. Contact with the plates is made by terminal wires or pig tails extending from the plates out through the ends of the container.

Figure 70.—Paper condensers.

Common sizes of these condensers are from .5 mf. to 50 mf. Larger paper condensers are made, but they are not common in radio circuits.

WORKING VOLTAGE

When you select a replacement paper condenser, be sure it has the correct WORKING VOLTAGE—w.v. All paper condensers are made to withstand a maximum voltage. If the condenser is subjected to a greater voltage than this, the insulation will BREAK DOWN or burn out. The condenser is then shorted and can cause serious damage to other parts of the radio.

If the working voltage of the circuit at the point where

the condenser is to be used is 400 volts, be sure that the replacement is rated for at least 400 WORKING volts. It would be better to replace a 400 w.v. condenser with one that is rated at 600 w.v.

A condenser that is marked "Max. V. 400" can withstand ONLY 400 volts, but this condenser cannot be used safely with a circuit that has a WORKING VOLTAGE of 400 volts. A 400-volt circuit may have SURGE voltages up to 600 or 700 PEAK volts. In that case, the surge would exceed the maximum voltage of the condenser and burn it out.

Condensers used in radio circuits are not normally required to carry large amounts of current, hence there is little danger of overloading them. If a condenser becomes excessively warm, you'll know that the condenser is either OVERLOADED or LEAKY.

You will find paper condensers used as COUPLINGS between two circuits, r.f. circuits, as by-passes, with tone controls, and in many other places.

ELECTROLYTIC CONDENSERS

The electrolytic condensers in figure 71 are commonly used as parts of a FILTER SYSTEM for power supplies. They are also used as by-pass condensers in circuits that carry audio-frequency currents.

As in paper condenser, the plates are metal foil. The dielectric is a porous paper that has been soaked in a liquid that becomes ionized. The plates and dielectric paper are encased in a moisture-proof cartridge to prevent evaporation of the electrolyte. The positive and negative leads are clearly marked.

When replacing these condensers in a radio set, be sure that you do not reverse the polarity of the condenser. If you are careless and do reverse the leads, the heat of the short-circuit will generate steam from the electrolyte and burst the cartridge.

The capacity of an electrolytic condenser is large. For peak voltages up to 600 volts you can use capacities up to 50 mf. Those designed to be used on working voltages up to 25 volts will often have capacities up to 400 mf. Large capacities and high working voltages require large condensers. The electrolytic condensers used with power supplies for transmitters are large.

Electrolytic condensers are DANGEROUS. Large condensers, when charged, are capable of killing a man. Do not play around with them. Before you start working on a transmitter, discharge the condensers with a SHORTING BAR that has an insulated handle. This is a MUST. Your first mistake may be your last.

Electrolytic condensers have a high RESISTANCE LEAKAGE RATE. It should be about 3 or 4 megohms. When you are checking these condensers, consult the service manual to see whether the leakage rate is a safe amount. If it is too low, replace the faulty condenser with one of the correct size.

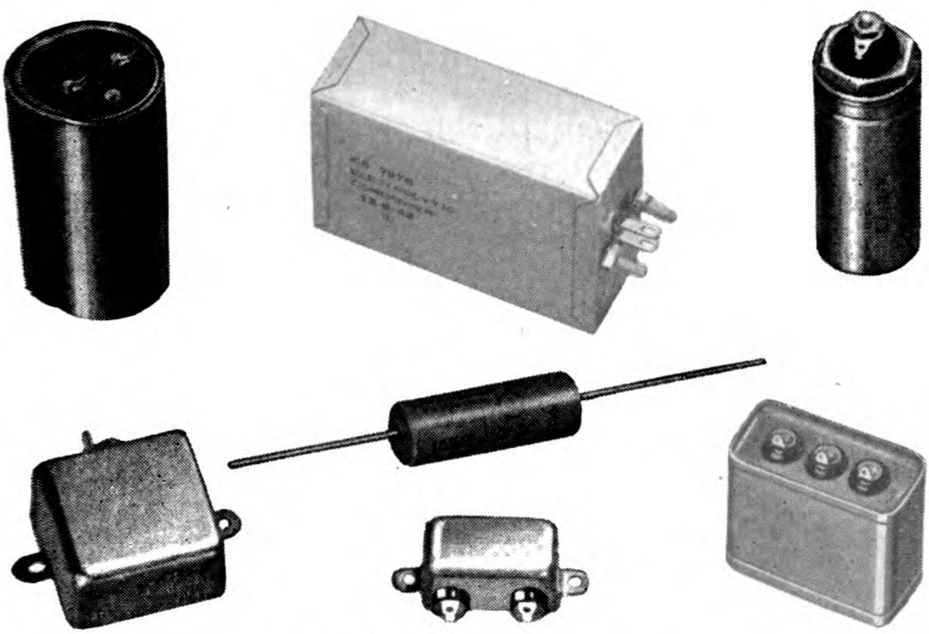


Figure 71.—Electrolytic condensers.

If an electrolytic condenser has been stowed for some time it may be necessary to cure it by applying the voltage to be used through a current-limiting resistor.

MICA CONDENSERS

The condensers in figure 72 are the smallest ones commonly used in radio circuits. A thin sheet of MICA is used as the dielectric. The plates are flat pieces of metal about the size of a three-cent stamp. Because of its small size, this condenser is frequently called a POSTAGE STAMP condenser. The newer types are encased in a plastic cover, and pigtail connections extend from the plates out through the edges of the case.

Capacities of these condensers range between 1,000 mmf. and 10 mf. These condensers are used extensively with r.f. to couple two circuits together and to by-pass high frequencies to ground.

LUMP AND DISTRIBUTED CAPACITIES

Lump capacities include the variable, mica, paper, electrolytic, and padder condensers, because they concentrate a large amount or lump of capacity in a small unit.

In any electrical circuit where two wires are close together, a condenser is formed. AIR is the dielectric. The longer the length of wire exposed, the larger is the capacity. Two PARALLEL wires have a larger capacity than wires at right angles.

A large amount of capacity exists between the insulated windings of a coil. Look at figure 73. The capacity formed by the windings of the coils are just as real as if small condensers were installed between each turn.

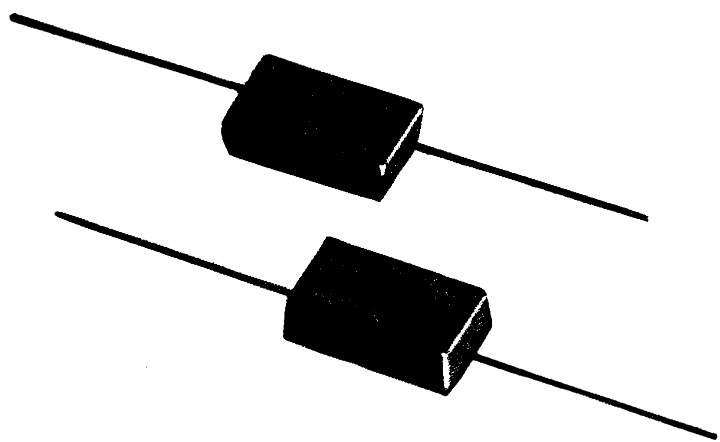


Figure 72.—Mica condensers.

Radios designed to be used on the low-frequency broadcast band are not seriously handicapped by this DISTRIBUTED CAPACITY of the coil and other wires. But at high frequencies, the distributed capacity of coils and wires is of major importance.

If the coil of figure 73 was used in a high-frequency oscillator, the distributed capacity between the windings would provide a low-resistance path for the r-f energy to ground. When you study oscillators later on, this will be fully discussed.

Another STRAY capacity is found between the elements

of the vacuum tube. This is INTERELECTRODE CAPACITY. At low audio frequencies, it is not serious. But at high RADIO FREQUENCIES it is such a handicap that special tubes were designed to reduce the effectiveness of this interelectrode capacity. You will hear more about this in later chapters.

CONDENSERS SHOW THEIR COLORS

You can determine the capacity and the voltage ratings of mica condensers by the spots of color placed on the casing. This system is handy and accurate. Learn it.

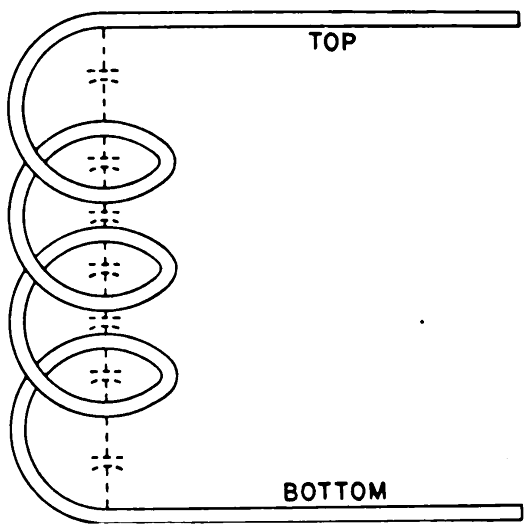


Figure 73.—Distributed capacity in a coil.

The condenser color code system is similar to the resistor color code. Both are based upon assigning a color to each of the 10 digits in the numeral system. Here are the colors and numbers again—

0	BLACK	5	GREEN
1	BROWN	6	BLUE
2	RED	7	VIOLET
3	ORANGE	8	GRAY
4	YELLOW	9	WHITE

The condenser in figure 74 is identified by the manufacturer's name or trade-mark written across the face of the condenser. Whenever you see a condenser with a trade-mark on the face, the spots are read from LEFT to RIGHT.

The type of condenser in figure 75 is identified by the three arrows pointing TOWARD THE LEFT. The spots are

read from RIGHT to LEFT. Do not make the mistake of turning this condenser around. These arrows always point to the left.

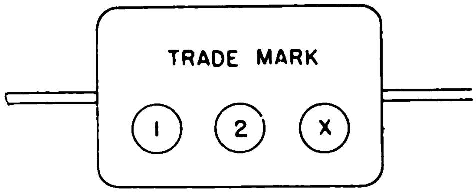


Figure 74.—Color code for mica condenser.

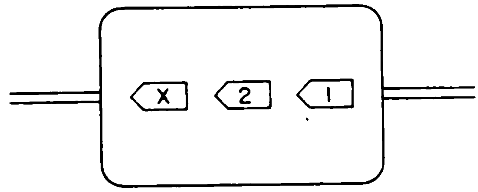


Figure 75.—You read from right to left.

Figure 76 shows the third type of mica condenser that you will use. Here you read the TOP line from left to right and the LOWER line from right to left.

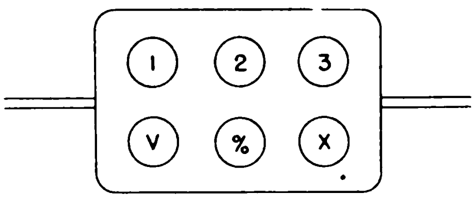


Figure 76.—Read this one "1, 2, 3, X, %, and V."

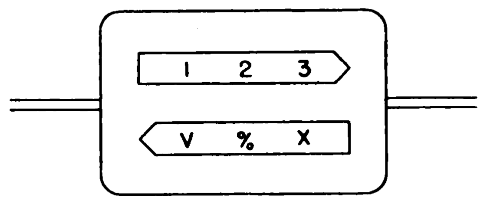


Figure 77.—Follow the arrows.

Figure 77 shows the fourth type of marking you will find on mica condensers. It is read by following the direction of the arrows. The top line is read from left to right, and the lower line from right to left.

To read the capacity of these condensers, the following system is used:

COLOR DESIGNATED BY	MEANING
1.	The color spot at this position indicates the FIRST digit in the capacity of the condenser. Thus, if the color is RED, the first number is 2. If the color is GREEN, the first number is 5.
2.	The color spot at this position indicates the SECOND digit in the capacity of the condenser.
3.	The color spot at this position indicates the THIRD digit in the capacity of the condenser.

X.	The color spot in position X indicates the number of ZEROS TO BE ADDED TO THE OTHER DIGITS. If this color is ORANGE, THREE ZEROS will be added to the digits indicated by the previous colors.
%.	This color spot indicates the percent of accuracy. This is known as the TOLERANCE of the condenser. A table of these values is given below.
V.	This color spot indicates the WORKING VOLTAGE of the condenser. These values are given in a table below.

TOLERANCE INDICATED BY COLOR CODE

BROWN	1%	VIOLET	7%
RED	2%	GRAY	8%
ORANGE	3%	WHITE	9%
YELLOW	4%	GOLD	5%
GREEN	5%	SILVER	10%
BLUE	6%	NO COLOR	20%

Tolerance is the percent of ACCURACY you can expect for the given capacity of the condenser. If a condenser is rated at 100 mmf. with 5 percent accuracy, the capacity of the condenser will be 100 mmf., plus or minus 5 percent of 100 mmf. The capacity will be at least 95 mmf. and not more than 105 mmf.

VOLTAGE RATINGS INDICATED BY COLOR CODE

BROWN	100	BLUE	600
RED	200	VIOLET	700
ORANGE	300	GRAY	800
YELLOW	400	WHITE	900
GREEN	500	GOLD	1,000
		SILVER	2,000

The voltages indicated by the various colors are SAFE WORKING VOLTAGES. For example, blue indicates a safe working voltage of 600 volts.

HOW TO READ CAPACITIES BY USING COLOR CODE

Want to work out the color code for a three-color condenser? Here's the code—

COLOR SPOT NUMBER	COLOR
1	RED
2	GREEN
X	BROWN

Look at the table on page 91. The first spot in the series is RED. That means "2", and is the first number in the capacity of the condenser. The second spot is GREEN. Green is "5". You now have 25.

The third spot, *X*, is BROWN. That tells you how many zeros to add to the number 25. Brown stands for "1," so add ONE ZERO to the number 25, and you get the final value, 250 mmf.

The capacities indicated by the color code system are always in MICROMICROFARADS (mmf.).

Suppose the colors are: 1—GREEN; 2—BLACK; X—YELLOW.

This condenser's capacity is 500,000 mmf. or 0.5 mf.

The capacity of the condenser indicated by figure 75 is read the same as figure 74, except that the colors are read from RIGHT to LEFT.

You read the capacity in figure 76 in a little different manner. For example: The colors are—

SPOT NUMBER	COLOR
1	YELLOW
2	ORANGE
3	GREEN
X	RED
%	GOLD
V	BLUE

The first color is YELLOW, which indicates the number 4, the first digit of the capacity. Spot 2 is ORANGE, which stands for the number 3. So the second number of the capacity is 3. Spot 3 is GREEN. On this type of condenser, the third color indicates the THIRD DIGIT in the capacity of the condenser. Green is the symbol for 5. Now you have the first three digits of the capacity, 435.

The color in position *X* indicates the number of ZEROS to be added to the other digits, and is RED, which stands for 2. Therefore, TWO zeros will be added to the 435, and the capacity will be 43,500 mmf.

The tolerance color spot % is GOLD, indicating 5 per-

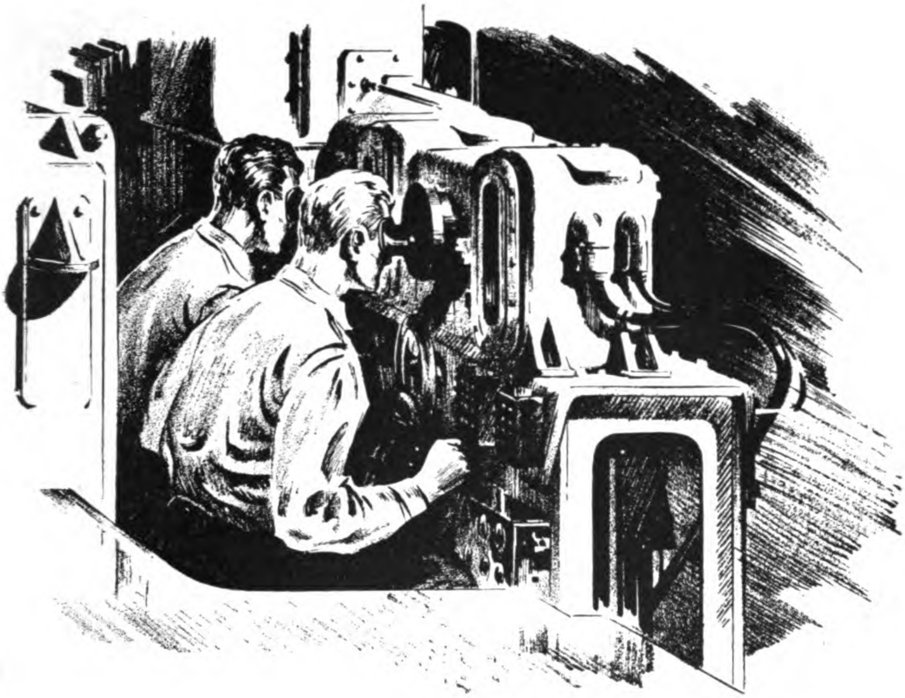
cent ACCURACY. And the voltage color spot *V* is BLUE, the symbol for 600 volts. Here's the full information about this condenser—

43,500 mmf. capacity
5 percent accuracy
600 volts, safe working voltage

A condenser has the following colors: 1—GRAY; 2—GREEN; 3—BLACK; X—BROWN; %—SILVER; V—SILVER. Figure out its characteristics. Then check your answer. That's right—

8,500 mmf. capacity
10 percent accuracy
2,000 volts safe working voltage

To read the value in figure 77, use the same procedure that you used in reading the values of figure 76. Watch the arrows, and you can't go wrong.



CHAPTER 10

THE TIME CONSTANT

ACCURATE TO MICROSECONDS

The combination of a condenser and resistor in series is a timing device. The operation of many parts of a radio circuit depends upon HOW FAST a condenser is able to charge and discharge through a resistor. A condenser and resistor in series is commonly called an R-C circuit.

If either the condenser or the resistor is LARGE, the charge and discharge rate will be SLOW. If either is SMALL, the rate will be FAST. By selecting the proper combination of condenser and resistor, the length of time required by the condenser to charge and discharge can be adjusted to allow a TIME DELAY that will cause a radio circuit to work properly.

THE RATE OF CHARGE

Remember—a condenser does not jump instantaneously to a FULL charge. It takes TIME. When the resistor and condenser in figure 78 are attached to a source of power, current starts to flow at a rapid rate. But the rate of flow BEGINS TO DECREASE immediately. This de-

crease in the rate of flow continues as long as the condenser is charging. When the condenser is nearing full charge, the rate at which the current flows is very slow.

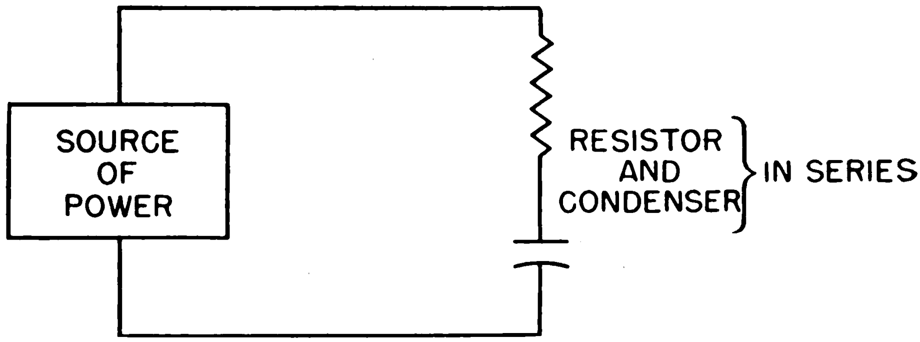


Figure 78.—An R–C circuit.

Since both R and C influence the RATE of charge of a condenser, a mathematical relationship has been devised between the resistance, the capacity, and the TIME required by the condenser to become charged. This relationship is known as the TIME CONSTANT. Here's what it is—the LENGTH OF TIME REQUIRED FOR A CONDENSER TO ASSUME A VOLTAGE EQUAL TO 62.5 PERCENT OF THE APPLIED VOLTAGE.

For example—if 10 volts is the APPLIED VOLTAGE, the charge on the condenser one TIME CONSTANT later, will be 6.25 volts. But apply 100 volts to the same condenser, and the voltage across the condenser one time constant later will be 62.5 volts. Regardless of what the applied voltage may be, the voltage across the condenser one time constant later WILL ALWAYS BE 62.5 percent of the applied voltage.

How about the rest of the charge for the condenser? During each succeeding time constant, the condenser WILL ADD 62.5 percent of the remaining applied voltage. For example, assume the original applied voltage to be 100 volts. One time constant later, the voltage across the condenser will be 62.5 volts. The remaining voltage will be—

$$100 - 62.5 = 37.5 \text{ volts.}$$

In the SECOND time constant, the condenser will assume an additional charge equal to 62.5 percent times 37.5 volts, or—

$37.5 \times 0.625 = 23.44$ volts during second time constant.

The charge on the condenser will now be—

$$62.5 + 23.44 = 85.94 \text{ volts.}$$

In the THIRD time constant, the condenser will assume an additional charge equal to 62.5 percent of the remaining applied voltage.

$$100 - 85.94 = 14.06 \text{ volts remaining.}$$

$$14.06 \times 0.625 = 10.6 \text{ volts during third time constant.}$$

The charge on the condenser will now be—

$$85.94 + 10.60 = 96.54 \text{ volts.}$$

In the FOURTH time constant, the condenser will assume 62.5 percent of the remaining applied voltage.

$$100 - 95.54 = 3.46 \text{ volts remaining.}$$

$$3.46 \times 0.625 = 2.16 \text{ volts during fourth time constant.}$$

The charge on the condenser will now be—

$$96.54 + 2.16 = 98.70 \text{ volts.}$$

In the FIFTH time constant, the condenser will assume 62.5 per cent of the remaining applied voltage—

$$100 - 98.70 = 1.30 \text{ volts remaining.}$$

$$1.30 \times 0.625 = 0.81 \text{ volt during fifth time constant.}$$

The charge on the condenser will be—

$$98.70 + 0.81 = 99.51 \text{ volts.}$$

At the end of the fifth time constant, less than ½ volt of the applied voltage remains. In the SIXTH, SEVENTH, EIGHTH, and all the others that are to follow, the condenser will continue to assume 62.5 percent of what's left of the applied voltage.

You say that the condenser will never assume a FULL CHARGE if it charges in this manner? You win—it will not. But it will soon get so near to full charge that you can't measure the difference.

Below is a table of applied and condenser voltages, figured through six time constants, with original applied voltage equal to 100 volts. At the end of these six time constants, the condenser is so near to being fully charged

that you can consider it fully charged. APPLIED VOLTAGE 100 volts.

TIME CONSTANT	TOTAL CONDENSER VOLTAGE (%)	VOLTAGE GAINED BY CONDENSER (%)	REMAINING APPLIED VOLTAGE (%)
0	00.00	00.00	100.00
1	62.50	62.50	37.50
2	85.94	23.44	14.06
3	96.54	10.60	3.46
4	98.70	2.16	1.30
5	99.51	0.81	0.49
6	99.82	.31	.08

In figure 79, a graph of the voltage across the condenser is shown by the SOLID black line. Notice that the voltage starts at zero. Also notice the rapid rise in voltage during the FIRST time constant. By the end of the fourth or fifth time constant, the rise in voltage is very slow.

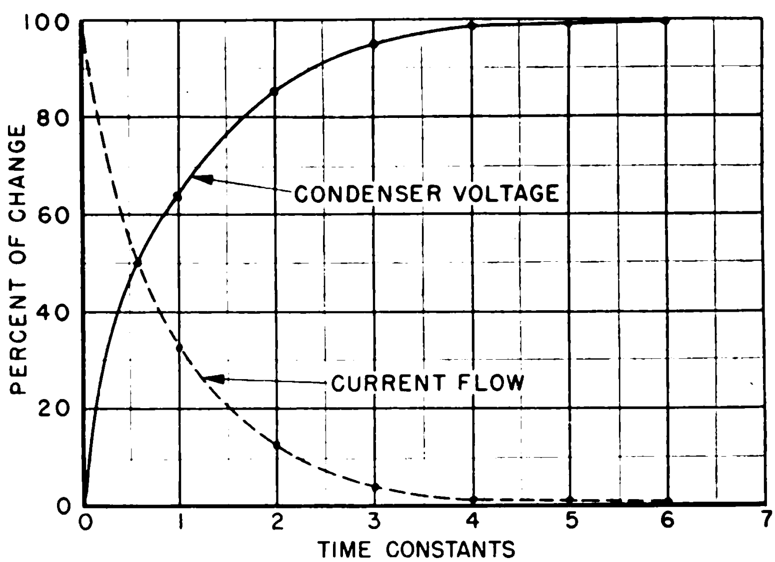


Figure 79.—Charging rate of a condenser.

The broken line in figure 79 shows the current flow during the charging period. When the switch in figure 78 is first closed, there is almost NO OPPOSITION to the flow of current into the condenser. The reason? The condenser has NO OPPOSING VOLTAGE. By the end of the first time constant, the opposing voltage is 62.5 percent of the applied voltage. According to Ohm's Law, if the voltage drops, the current flow will drop. That's true in this case. AS THE CONDENSER ASSUMES A CHARGE, THE VOLTAGE ACROSS THE CONDENSER SUBTRACTS FROM THE TOTAL APPLIED VOLTAGE. Therefore, the voltage tending to move

the electrons into the condenser is less. The rate of flow will become less and less and will stop completely when the voltage across the condenser equals the applied voltage.

The broken line in figure 79 shows the current flowing in the circuit to be MAXIMUM at the BEGINNING of the first time constant. At the end of this time constant, the value of current flow has dropped by 62.5 percent of its original value. The RATE OF DECREASE in the current flow becomes less and less for each succeeding time constant. At the end of the SIXTH time constant the current is a mere trickle.

Look at figure 79 again. When current is MAXIMUM, the voltage across the condenser is zero. When the current is ZERO, the voltage across the condenser is maximum. This gives a PHASE SHIFT of 90 degrees. Since the current begins to flow BEFORE a voltage is created, you say that the CURRENT LEADS THE VOLTAGE.

HOW LONG IS A TIME CONSTANT?

The length of a time constant in seconds depends upon the CAPACITY of the condenser and the total amount of RESISTANCE in the circuit. As you know, resistance tends to retard the flow of current. The larger the resistance, the more the current will be retarded. Since the condenser and the resistor influence the time constant, you always express the time constant as the PRODUCT of the resistance and the capacity of the condenser.

Resistance × *Capacity* = (*Produces*) *Time Constant.*

The following table shows the time constants for several combinations of resistance and capacitance.

RESISTANCE (IN MEGOHMS)		CAPACITANCE (IN MICROFARADS)		TIME CONSTANT (IN SECONDS)
5.0	×	3.0	=	15.0
2.0	×	0.01	=	0.02
1.5	×	2.0	=	3.0
0.3	×	0.1	=	0.03
0.2	×	0.005	=	0.001
0.1	×	0.01	=	0.001

Resistance is given in MEGOHMS, capacity is expressed in MICROFARADS, and the time constant will be given in

SECONDS. Thus, 1 megohm multiplied by 1 microfarad will produce a time constant of 1 second.

In a circuit with a resistance of 1 megohm and a condenser with a capacity of 1 microfarad, it will take 1 second for the condenser to assume a charge equal to 62.5 percent of the applied voltage. For each succeeding second, the condenser will assume 62.5 percent of the REMAINING applied voltage. Thus, if a 1-microfarad condenser is in series with a 1-megohm resistance, SIX seconds will pass before the condenser can be considered to be fully charged.

Remember—the length of time needed to charge a condenser DOES NOT depend on the applied voltage. The length of time required to charge a condenser is determined solely by the SIZE of the condenser, and the AMOUNT OF RESISTANCE in the circuit.

You'll usually prefer to express the time constant in MICROSECONDS. A microsecond is one one-millionth—$\frac{1}{1{,}000{,}000}$—of a second. To convert a time constant from seconds to microseconds, multiply the time constant in seconds by 1,000,000.

TIME CONSTANT IN SECONDS	MULTIPLIED BY	TIME CONSTANT IN MICROSECONDS
0.02	1,000,000	20,000
0.001	1,000,000	1,000
0.03	1,000,000	30,000
3.0	1,000,000	3,000,000
0.0005	1,000,000	500
0.00003	1,000,000	30

When you're using microseconds as the time constant, you'll use OHMS instead of megohms. The relationship then becomes—

$$\text{RESISTANCE IN OHMS} \times \text{CAPACITANCE IN MICROFARADS} = \text{TIME CONSTANT IN MICROSECONDS}$$

The following table expresses time constants in microseconds—

RESISTANCE IN OHMS	CAPACITANCE IN MICROFARADS	TIME CONSTANT IN MICROSECONDS
50,000	0.1	5,000

100,000	0.3	30,000
200,000	0.004	800
400,000	0.0001	40
2,000,000	0.04	80,000

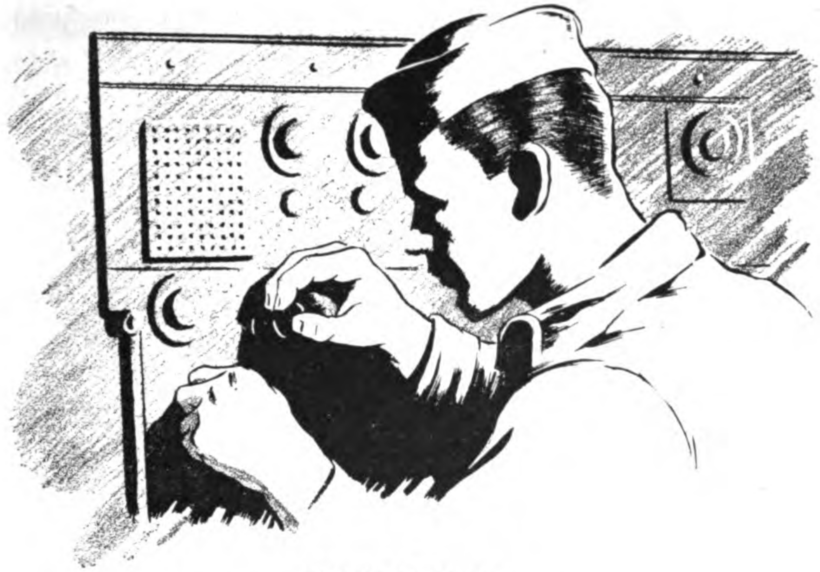
SUMMARY OF TIME CONSTANTS

Here are the important points about time constants—

FIRST—The TIME CONSTANT is the time it takes a condenser to assume a charge of 62.5 percent of the applied voltage, regardless of what the applied voltage may be. For each succeeding time constant, the condenser will charge 62.5 percent of the REMAINING applied voltage.

SECOND—The LENGTH of a time constant is measured as the produce of the RESISTANCE and CAPACITANCE. If the resistance is expressed in MEGOHMS, the capacitance in MICROFARADS, the time constant will be expressed in MICROSECONDS.

THIRD—Any resistor and condenser in series is called an R-C CIRCUIT.



CHAPTER 11

RESONANCE

LIKE YOUR RATTLING OL' FORD

Ever sit at the wheel of your old Model A and say, "Now we're doing 40; I can tell by the rattles."? If you changed speed to 30 or to 50 miles an hour, the rattles and vibrations also changed. You associated the various speeds of your automobile with the different rattles and vibrations that were present.

What produced those rattles? Why did certain rattles show up at one speed, and other rattles at other speeds? Here's why—

You know that all engines vibrate. At different speeds, the FREQUENCY of the vibration is different. And every fender, bumper, and bolt in your automobile has its NATURAL FREQUENCY of vibration. If the engine is running at the correct speed to generate the frequency of the right front fender, that fender will vibrate. If the engine is running at a speed that will produce the frequency of the rear bumper, the bumper will vibrate. And so on throughout the entire automobile.

The phenomenon of natural vibrations is common, but its importance is easily overlooked. It is part of every MECHANICAL and ELECTRICAL device. Of course you may have trouble finding the natural frequency of vibration for some objects, but the frequency at which an object will start vibrating is its RESONANT FREQUENCY.

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RESONANCE refers to vibrations. The frequency at which an object will vibrate depends upon its structure.

SPECIAL RESONATORS

You can REINFORCE the sound of a musical note by using special RESONATORS. Resonators on the xylophone are round metal tubes, the violin has a wooden box, and the piano has a flat sounding board. These resonators are scientifically constructed to reinforce the vibrations coming from a weak source.

On a pipe organ or flute, the resonator serves as the SOURCE of vibration. By changing the length of the pipes in the organ or in the flute, the frequency of the notes produced can be changed.

ELECTRICAL RESONATORS

You'll run into special resonators in electricity. They are usually a combination of a coil *L* and a condenser *C*, connected in SERIES, as in figure 80*A* or in PARALLEL as in figure 80*B*. Resistance *R* indicates the SUM of the d-c resistance in the whole circuit.

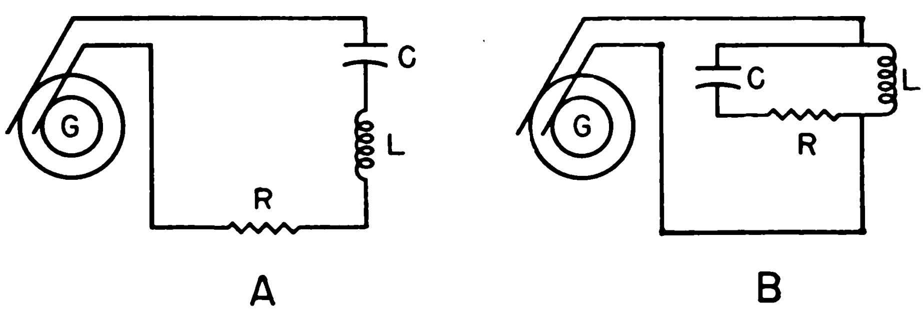


Figure 80.—Series and parallel L–C connections.

Electrical resonators are sources of ELECTRICAL VIBRATION. Also, just as the frequency of an organ note depends upon the length of the pipe, the frequency of an electrical resonator depends on the ELECTRICAL length of the L-C circuit.

The electrical length of an L-C circuit may be INCREASED by using a coil with greater inductance or a condenser with greater capacity, or both. To DECREASE the electrical length, you reduce the inductance of the coil or the capacity of the condenser, or both. The usual way of changing electrical lengths in a radio circuit is to change the capacity of the condenser, you do this when you tune a receiver.

SERIES AND PARALLEL RESONANT CIRCUITS

An organ pipe that is open at both ends has entirely different characteristics from a pipe that is closed at one end. Similarly, an electrical resonator with the condenser in series with the coil has characteristics that are entirely different from a resonant circuit where the coil and condenser are in parallel.

SERIES RESONANT CIRCUITS

Figure 81 is a diagram of a series resonant circuit. The coil *L* is connected in series with condenser *C*. The generator *G* is the source of an alternating voltage. All the resistance in the circuit is represented by *R*.

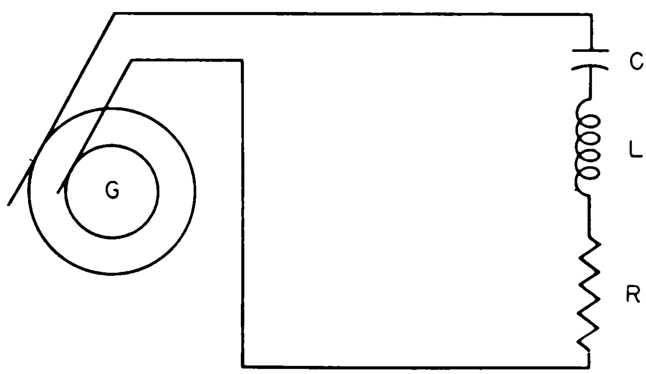


Figure 81.—Series L–C circuit.

Here's how this circuit works—

In the coil *L,* the current tends to LAG behind the voltage. The amount of lag depends upon the frequency of the current. The HIGHER the frequency of the current, the GREATER is the lag.

The condenser *C* causes the current to tend to LEAD the voltage. The amount of this lead also depends upon the frequency. The higher the frequency, the SMALLER is the angle of lead.

With ZERO frequency—or DIRECT CURRENT—the angle of LAG for the inductance is also zero. But at zero frequency, the angle of LEAD for the condenser is near 90 degrees.

As the frequency rises, the coil lag INCREASES and the condenser lead DECREASES. Thus, if the frequency is raised high enough, the angle of lag will eventually EQUAL the angle of lead.

When the angle of lead is equal to the angle of lag,

the coil and condenser will be working in perfect teamwork, and the circuit is said to be at RESONANCE. The current caused by the collapsing field of the coil will be absorbed by the charging condenser. By the time the condenser has assumed full charge, the field will have collapsed completely and will have built a new field in a direction OPPOSITE to the original. At this point, the cycle reverses itself again. The condenser will begin to discharge and the field will collapse in reverse direction. This charging and discharging of the condenser and the expanding and collapsing of the field will continue as long as the generator delivers current at the resonant frequency.

CHARACTERISTICS OF SERIES L–C CIRCUIT

But what will happen if the generator is delivering an a.c. that is NOT at the resonant frequency? The condenser will discharge in opposition to the collapsing field of the coil. When the condenser attempts to charge, the field will try to prevent it—the coil and the condenser OPPOSE each other.

The same thing is true in a series L-C circuit, for all frequencies EXCEPT the RESONANT. For all except the resonant frequency, the confusion is so great that the resistance to the movement of electrons is MAXIMUM, and the following two conditions exist—

1. The IMPEDANCE of a series L-C circuit is MAXIMUM.
2. The CURRENT flow is MINIMUM, usually near zero.

How about the RESONANT FREQUENCY? Everything is fine as silk. The opposition to the flow of current is minimum—opposed only by the d-c resistance of the wire. Thus at the resonant frequency, the following two conditions exist—

1. The IMPEDANCE of a series L-C circuit is MINIMUM.
2. The CURRENT flow is MAXIMUM.

IMPEDANCE IN A RESONANT CIRCUIT

You can define resonance by expressing it in terms of reactance. Since X_L increases and X_C decreases as the frequency increases, there will be some place along the line where X_L and X_C are equal. When X_L EQUALS X_C, the circuit is RESONANT.

Thus in the equation for finding the impedance of an L-C circuit—

$$Z = \sqrt{R^2 + \left(2\pi FL - \frac{1}{2\pi FC}\right)^2}$$

At resonance......... $2\pi FL = \frac{1}{2\pi F\,C} = 0$

Therefore............ $Z = \sqrt{R^2 + 0}$

$$Z = R$$

This resistance R at the resonant frequency is the d-c resistance of the wire plus other forms of opposition that are characteristic of circuits carrying r-f current. ALL of this resistance is known as the EFFECTIVE RESISTANCE of the circuit.

PARALLEL L–C CIRCUITS

Figure 82 is a diagram of a parallel L-C circuit, where L is the coil, C is the condenser, and G is an a-c generator. The total resistance of the circuit is R. Notice that the a.c. from the generator is applied to the circuit at points A and B. The coil and condenser form PARALLEL paths for the current. The way the voltage is applied to the coil and condenser determines whether it is a series or parallel circuit. Come common application of this principle are pointed out in the following chapters.

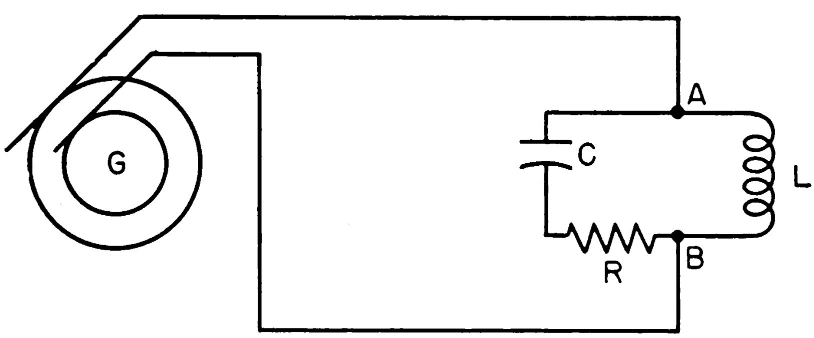


Figure 82.—Parallel L–C circuit.

Current in a parallel L-C circuit at resonance acts just as it did in the series L-C circuit. At the RESONANT FREQUENCY, the coil and condenser are working in perfect harmony—the current delivered by the collapsing field is absorbed by the discharging condenser. And on the other half of the cycle, the current from the discharging con-

denser will be absorbed by the coil to build up the field in the OPPOSITE direction. Hence, at the resonant frequency, the flow of current WITHIN the circuit formed by the coil and condenser will be MAXIMUM.

But how about the CURRENT FROM THE GENERATOR? Does the L-C circuit offer a low or a high impedance? Since the coil and condenser are working with such perfect team work, the circuit cannot take time out to carry ANY of the current supplied by the generator. Therefore, at the RESONANT frequency, the following two conditions are true—

1—The IMPEDANCE is MAXIMUM.

2—The CURRENT flow through the circuit is MINIMUM.

SUMMARY—CHARACTERISTICS OF A PARALLEL L-C CIRCUIT AT RESONANCE

At the resonant frequency, the IMPEDANCE of a parallel L-C circuit is MAXIMUM, and the CURRENT flowing through the circuit is MINIMUM. The flow of current from coil to condenser and from condenser to coil is maximum WITHIN the circuit at RESONANCE.

For all frequencies OTHER THAN the resonant frequency, all the preceding conditions are REVERSED. The impedance of the circuit is MINIMUM, the current flow through the circuit is MAXIMUM. Within the L–C circuit, confusion will prevail. Current flow will be at a MINIMUM.

CURRENT FLOW WITHIN A PARALLEL L–C CIRCUIT AT RESONANCE

The current flowing within a parallel L-C circuit at resonance is very much like a pendulum. Once started, it will continue to swing back and forth in shorter and shorter arcs until the resistance offered by the air and the pivot will bring it to a stop. If a small amount of energy—just enough to overcome the resistance—is added on each swing, the pendulum will continue to move forever.

So it is with the current flow in a parallel L-C circuit. Once the oscillations—flow of current—are started, the collapse of the field around the coil and the discharge of the condenser will keep the current flowing back and forth until the resistance of the circuit brings it to a STOP.

If the circuit had no resistance, the oscillations would continue forever. But there is no such thing as a circuit without resistance. Thus, if the oscillations within the L-C circuit are to be sustained, enough energy must be added to overcome the resistance of the circuit. Therefore, at the resonant frequency, there will be a small amount of current flowing through the circuit—just enough to overcome the resistance of the circuit.

THE "Q" OF A COIL

You can see that a coil with a LOW RESISTANCE will be more efficient than a coil that has a high resistance. The relationship of the REACTANCE of the coil to its RESISTANCE

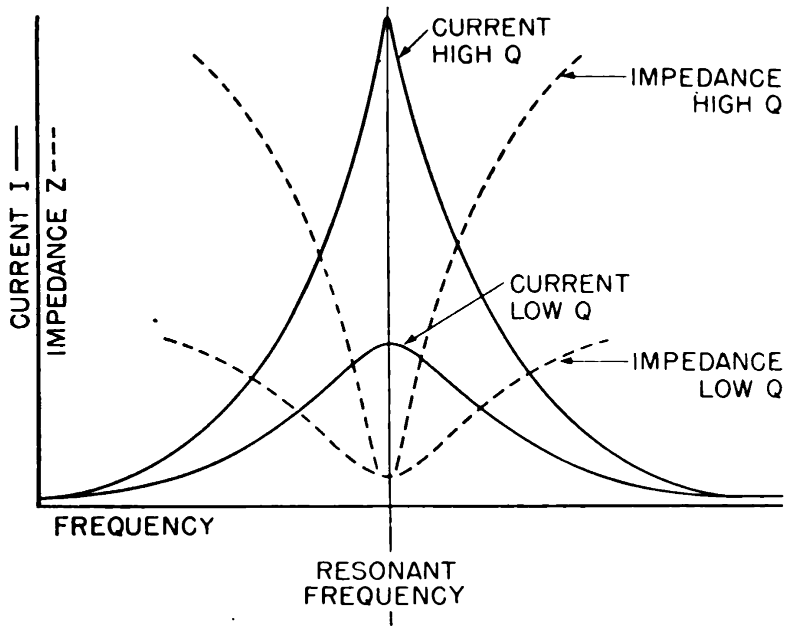


Figure 83.—Effect of "Q" in a series L–C circuit.

is a measure of the EFFICIENCY or the QUALITY of the coil. This measure of quality is known as the "Q" of the coil and is expressed this way—

$$Q = \frac{X_L}{R}$$

You understand that if the RESISTANCE of the coil can be made SMALL, the Q will be LARGE. The process of reducing the R of a coil to a point near zero is important in oscillators. You will hear about this again in this text.

The other point of consideration in the design of oscillators is the reactance X_L of the coil. You already

know that the reactance increases as the frequency rises. Result—a coil will become more and more efficient as the frequency RISES. That is true up to a certain point. The Q will become very large, but since the R of the coil is not reduced, a large amount of energy will be used to overcome this opposition.

All energy used to overcome the resistance of the coil will be dissipated as heat. The amount of this heat can be great enough to cause the coil to burn. Coils used with HIGH r.f. will have a LOW inductance. This helps prevent the coil from being destroyed.

EFFECT OF "Q" IN RESONANT CIRCUITS

The importance of Q in series and parallel resonant circuits can be easily understood by taking a good look at figures 83 and 84.

In figure 83, the solid lines show the amount of CURRENT flowing through a series L-C circuit. The broken line represents the IMPEDANCE of the circuit. There are two points to observe—

First: With a coil having a HIGH Q, the current rises ABRUPTLY and to a HIGH value at the RESONANT FREQUENCY, while a coil with a LOW Q has a much lower current value, and the slope of the current is not steep.

Second: Since the slope of the curves for a coil with a high Q is steep, the sharpness of discrimination between the resonant and nonresonant frequencies will be greater with a coil having a high Q.

As you will soon learn, coils and condensers are used to tune a radio. Radios equipped with coils having a HIGH Q are able to TUNE-OUT and TUNE-IN stations with broadcast frequencies that are very close together. A radio that has coils of low Q cannot separate two stations that are close together in their frequencies of broadcast.

You have seen the low Q type of radio many times—the receiver that you buy for $9.98 at the corner drug store for example. You can get many stations. The only difficulty is in picking up the baseball game you want to hear without the program of "Mrs. Zilch's Suddzy-Duddzy Snow-White Washing Powder" coming through in the background.

Radios that can separate adjoining stations easily are

said to be SELECTIVE. Needless to say, the Navy's radios are EXTREMELY SELECTIVE.

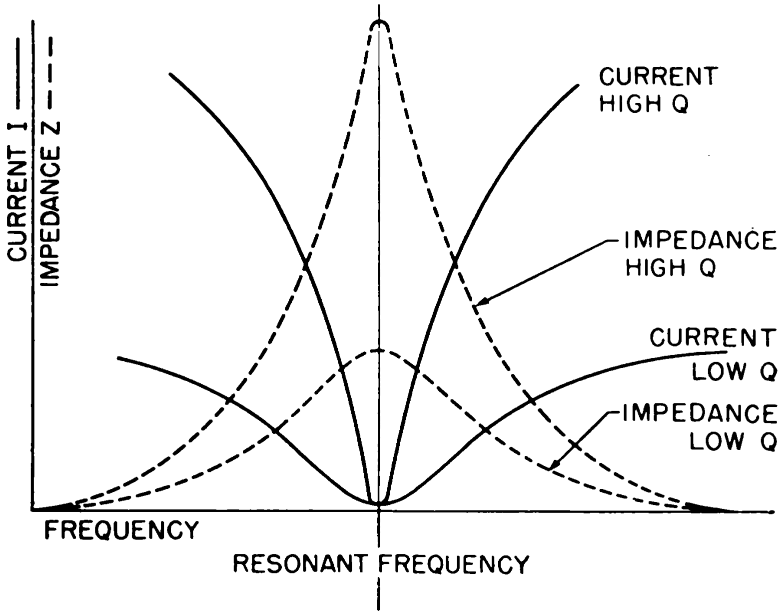
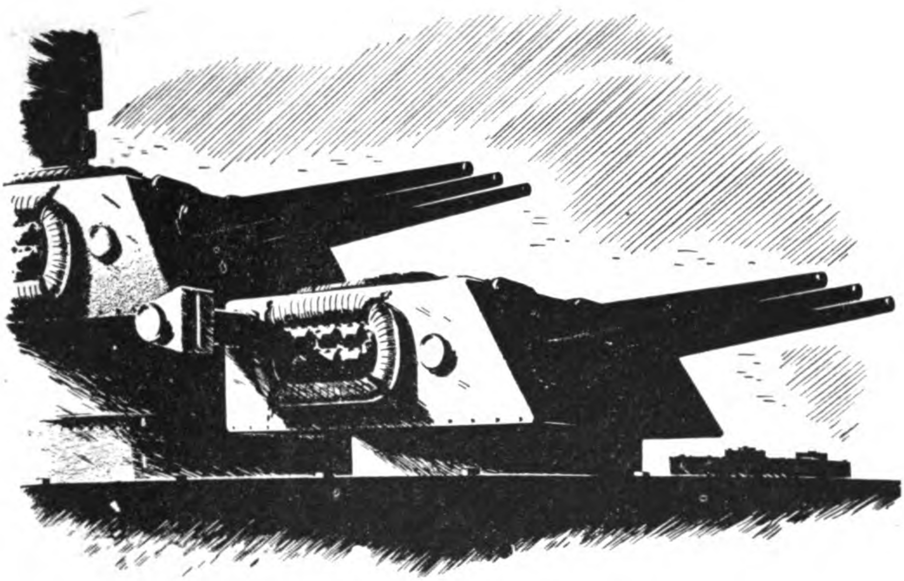


Figure 84.—Effect of "Q" in a parallel L–C circuit.

Figure 84 shows the relationship between current and impedance in a parallel L-C circuit having high and low values of Q. Notice the shapes of the curves. They are the same, except the impedance is MAXIMUM and current is MINIMUM. Notice also that the coil with a high Q has curves that are STEEPER than those of the coil with a low Q.



CHAPTER 12

FILTERS

LOW PASS FILTER

You'll be on familiar ground in this chapter. You will run into some common examples of L-C circuits in radio. Since you already understand series and parallel resonant circuits, this chapter should be easy reading.

The LOW PASS filter is commonly used in the output of power supplies to iron out the wrinkles in the d.c. as it comes from the rectifier tube. For the present, pass over the rectifier tube—a whole chapter is devoted to that subject later.

In figure 85, the circuit contains an a-c generator *G*, a choke coil *L*, two condensers C_1 and C_2, and the resistance *R*, for the load. This load may be a receiver or a transmitter.

Notice that inductance *L* is IN THE LINE—it will offer a LARGE reactance to ALL a.c. Condenser C_1 is connected between the coil *L* and ground. The condenser will offer a LOW reactance to a.c. Therefore, any HIGH-FREQUENCY alternating current delivered by the generator will be STOPPED by the coil *L*. Since the reactance of the condenser C_1 is LOW, most of this alternating voltage will be carried to the ground.

Any alternating current that does get through coil *L*

will be carried to the ground by condenser C_2, since the condenser reactance is low in comparison to the resistance R of the circuit.

The curve at the right shows what happens to the a.c.

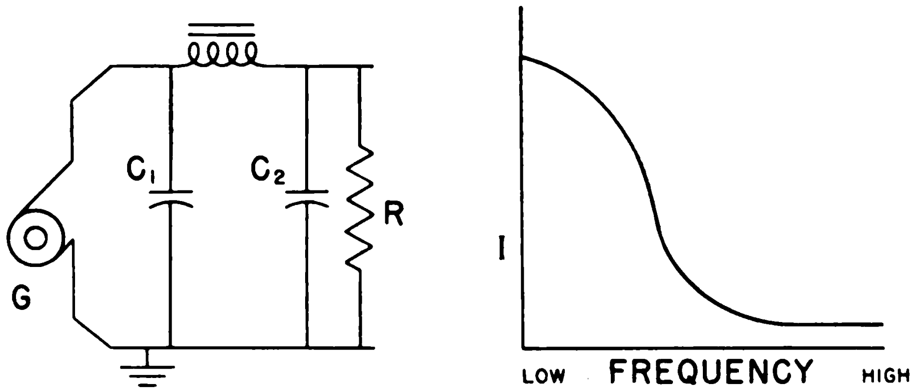


Figure 85.—Low-pass filter.

as the frequency rises. At low frequency, all the current is passed. But as the frequency rises, less and less current can get through the choke coil. Remember this principle from BASIC ELECTRICITY? If two resistances are in parallel, the SMALLER resistance will carry the LARGEST amount of current. And that's true with a.c. In an a-c circuit, the SMALLER REACTANCE always carries the most current. You'll see the application of this principle in all the filter circuits that are to follow.

HIGH-PASS FILTER

Figure 86 is a HIGH-PASS filter circuit. In this case,

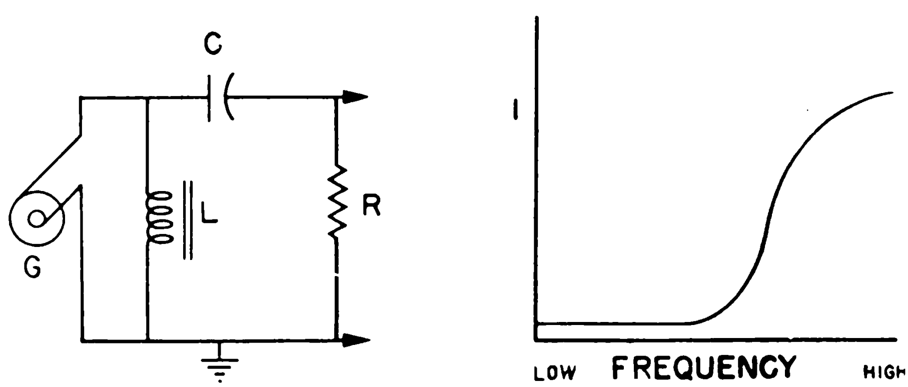


Figure 86.—High-pass filter.

a condenser C which offers LOW REACTANCE to a.c., is IN THE LINE, and the choke coil L which offers HIGH REACTANCE to a.c. is connected to ground.

At ZERO frequency, which is d.c., the condenser acts as an INSULATOR. But at LOW frequency, the reactance of the coil L is small. Thus, at zero frequency, ALL the current will flow to ground through the coil and none will pass through the condenser. As the frequency rises, the reactance of the condenser will become less and less, and the reactance of the coil will be rising. At HIGH frequencies, the reactance of the coil will be great and that of the condenser will be small. Then almost ALL the current will be flowing through the condenser into the line and none will pass through the coil.

BAND-PASS FILTER

The band-pass filter is used to PASS A SINGLE BAND of frequencies and to suppress all other bands.

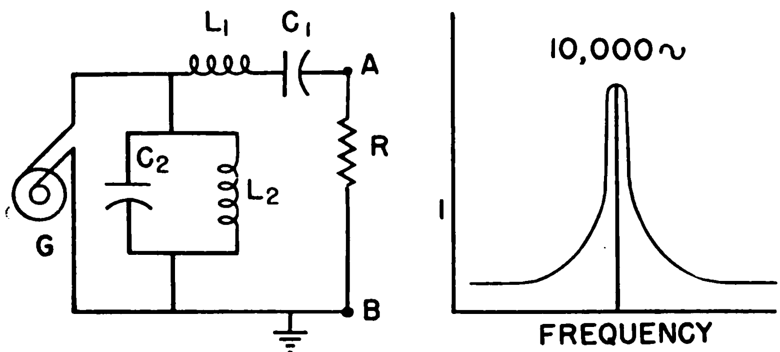


Figure 87.—Band-pass filter.

In the circuit of figure 87, the 10,000 cycle frequency can pass, but all other frequencies of current are stopped. Look at the circuit. Coil L_1 and condenser C_1 form a SERIES circuit. Coil L_2 and condenser C_2 form a PARALLEL circuit. BOTH circuits have a RESONANT FREQUENCY of 10,000 cycles. At that frequency, L_1 and C_1 offer a LOW REACTANCE, and L_2 and C_2 offer a HIGH REACTANCE. Therefore 10,000 cycle a.c. flows through L_1 and C_1 with great ease, but the parallel circuit formed by L_2 and C_2 has an impedance high enough to effectively stop the flow of current to the ground.

In the circuit of figure 88, the positions of the series and the parallel L-C circuits are reversed. As in figure 87, both circuits are tuned to the frequency of 10,000 cycles. At that frequency, L_2 and C_2 will offer a HIGH reactance, and L_1 and C_1 offer a LOW reactance. Thus, at the resonant

frequency, the PARALLEL circuit will BLOCK the flow, but the SERIES circuit will carry the a.c. to GROUND.

The circuits of figures 87 and 88 can be tuned to respond to any desired frequency. If the Q of the coil is

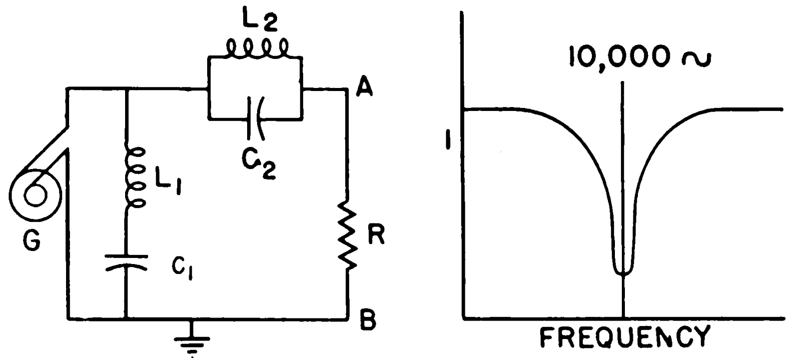


Figure 88.—Band-suppressor filter.

HIGH, the bands suppressed or passes will be NARROW. If the Q of the coil is LOW, the bands will be WIDE.

BAND-PASS AND BAND-STOP FILTERS

Figure 89 shows an application of the BAND-PASS FILTER. This is the antenna circuit of a radio used to listen to a selected station. Parts L_1 and C_1 form a SERIES circuit; L_2 and C_2 form a PARALLEL circuit, and L_3 and C_3 make up the TUNING circuit of the radio receiver. Coil L_4 is the primary and L_3 is the secondary of the antenna coil.

The wave trap includes the units enclosed within the

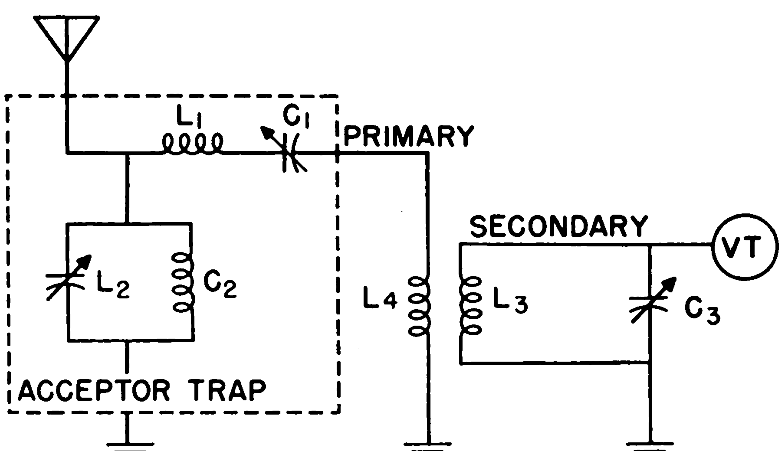


Figure 89.—Band-acceptor wave trap.

broken lines at the left of figure 89. Notice that the variable condensers are used so you can tune the trap to the desired frequency.

Here is how the wave trap works. You have been ordered to listen to a station operating on a frequency of 1710 kilocycles. On both sides of that frequency are other stations that interfere with your assignment. To overcome this interference, you tune the trap sharply to 1710 kilocycles and effectively cut out the interfering stations. Your 1710-kc station still comes through clearly.

BAND-REJECTOR FILTER

In figure 90, the positions of L_1–C_1, and L_2–C_2 are reversed from those of figure 89. Because of this reversal, the action of the trap is also reversed—the circuit will STOP a certain band of frequencies from getting to the receiver, but will let all others through.

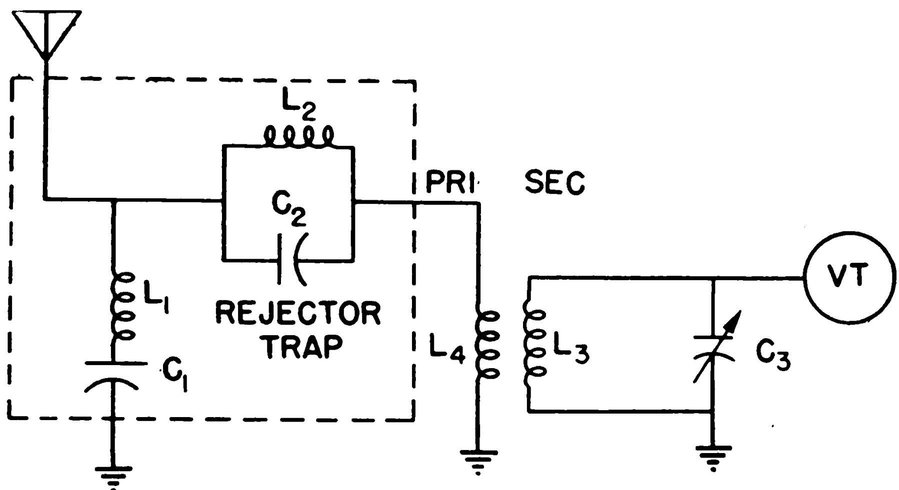


Figure 90.—Band-rejector trap.

Circuits of this band-rejector type are used when you have one transmitter interfering with the reception of the station you want. To cut out the interference, tune the trap to the frequency of the interfering station. At that frequency, the PARALLEL circuit formed by L_2 and C_2 will offer a HIGH IMPEDANCE, and the SERIES circuit formed by L_1 and C_1 will offer a LOW IMPEDANCE to the flow of current.

Then it's the same old story—the high impedance formed by the parallel circuit will effectively block the flow of energy from the interfering station, while the low impedance path of L_1–C_1 will carry all this energy to ground. All other frequencies will be carried to the receiver without hindrance.

SERIES AND PARALLEL L-C CIRCUITS IN TUNING A RECEIVER

You tune a receiver by using series and parallel L-C circuits. You can tune a receiver by using only one circuit, but usually several circuits are used. Navy receivers have many tuning circuits.

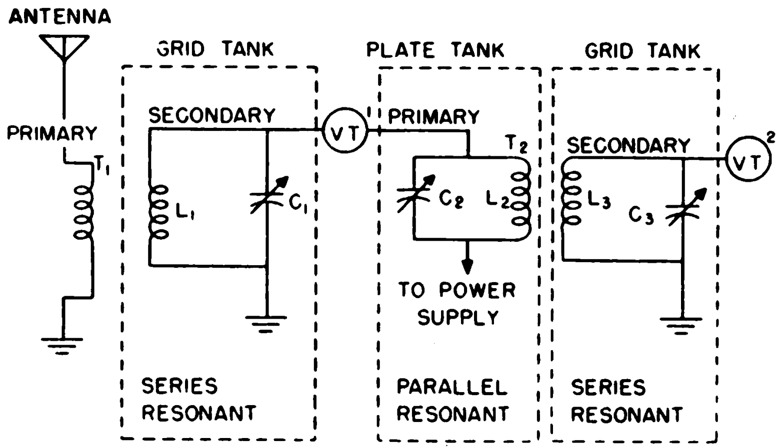


Figure 91.—L–C circuits used in tuning a receiver.

In figure 91, T_1 and T_2 are r-f transformers. The primary of T_1 is connected to the antenna, and is NOT TUNED. Coil L_1 is the secondary of T_1, and, with C_1, forms a tuned circuit leading into vacuum tube VT_1. The outlet of this vacuum tube leads into transformer T_2. The primary L_2 of this transformer and condenser C_2 form another tuned circuit. The secondary of this transformer L_3, and condenser C_3 also form a tuned circuit. These tuned circuits are called TANK CIRCUITS. This type of input to a vacuum tube is a GRID TANK circuit, and the output from the vacuum tube is a PLATE TANK circuit. You will run into these tank circuits in receivers and transmitters.

GRID TANKS ARE SERIES CIRCUITS

On paper, the grid tank circuits look very much like those in the plate circuits, but they are quite different in their electrical performance. You recall the statement—"the way the voltage is applied to the circuit determines whether a circuit is series or parallel"? Consider that point now.

Figure 92 shows the tank circuits formed with transformer T_2. The plate tank circuit formed by the primary L_2 and the condenser C_2, is a parallel L-C circuit. Here's

why: The a.c. from VT_1 is applied equally to the parallel paths formed by the condenser and coil. Thus the condenser and coil provide PARALLEL paths for the a.c.

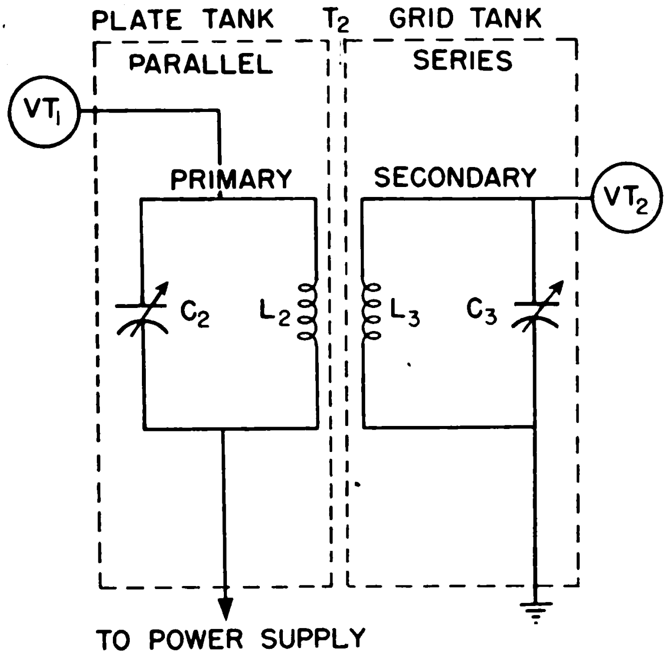


Figure 92.—Plate and grid tank circuits.

Now to find the voltage source for the grid tank formed by the secondary of transformer L_3 and condenser C_3. Since T_1 is a transformer, the voltage is INDUCED in L_3, the secondary of the transformer.

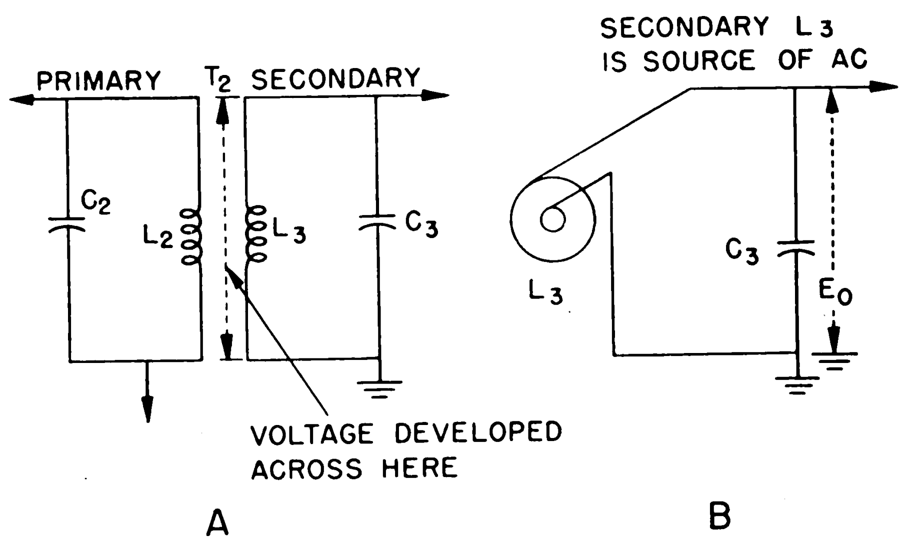


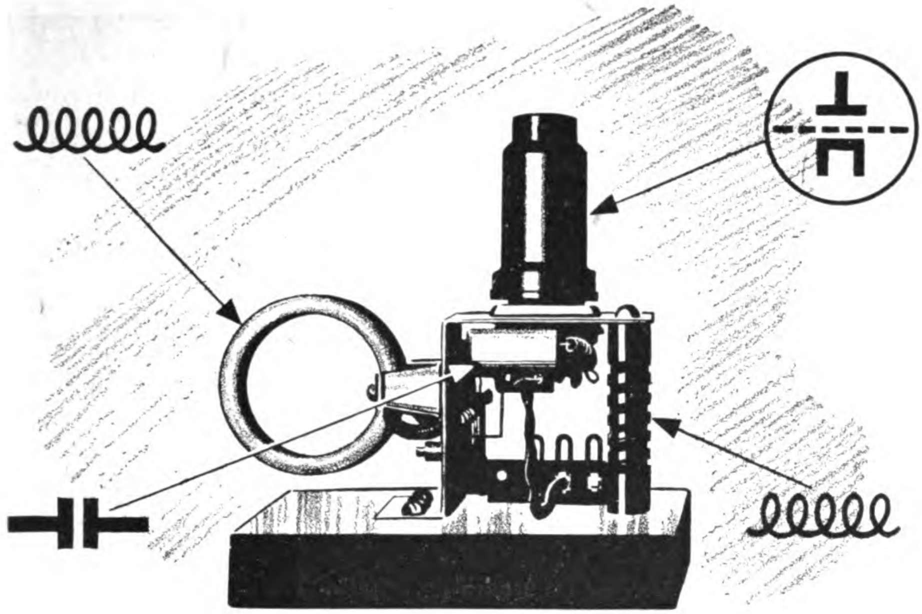
Figure 93.—Grid tank is a series L–C circuit.

Now look at figure 93. All the voltage in the grid tank circuit is developed in the secondary L_3 of the trans-

former. But the induced voltage is not applied equally to the coil and the condenser. The COIL is the SOURCE of the voltage as far as the grid tank is concerned, and can be considered to be an a-c GENERATOR, as shown in figure 93*B*. The condenser C_3 then becomes the LOAD for the generator. The voltage output E_o will be developed as the condenser charges and discharges.

The current flows back and forth in the grid tank circuit in the same manner as the current in the plate circuit. At the resonant frequency, MAXIMUM voltage is developed across the condenser.

There are two reasons for pointing out how grid and plate circuits operate. First, to prevent you from getting confused, and second because you will hear the grid tank referred to as a SERIES circuit and the plate tank as a PARALLEL circuit. You ought to know WHY. If the circuits aren't crystal-clear now, don't let it worry you—you'll see it all later.



CHAPTER 13

SCHEMATIC DIAGRAMS

DRAW A PICTURE OF IT

Suppose you let fly at Grandma with this line of chatter—"*Johnson, swinging from the wrong side of the platter, fanned the ozone twice, then lashed a grasshopper to Meat-Hooks O'Malley, covering the look-in corner, who dug it out of the dirt and rifled the apple to Schlepperman on the keystone. Schleppy pivoted and flipped to initial sacker Sewell, nipping Box-Car Gonzales by an eye-lash and completing the prettiest 'round-the-horn double-killing seen since Pie Traynor covered the hot corner like a blanket for the old Corsairs.*"

Grandma would be confused, obfuscated, flustered, discomposed—in other words, she'd be in a fog because she wasn't hep to your patter.

There's a technical language in Radio—a language made up, not of words, but of SYMBOLS. And you'll find yourself in a terrific fog if you try to trace a radio circuit, check a diagram, or shoot some trouble without knowing the language.

Radio symbols save space, as well as time. Confucius is alleged to have said that "one picture is worth ten thousand words." If Confucius had known about radio

and circuit diagrams, he'd have raised the ante to twenty or thirty thousand words per picture.

Here's a little trick. From the word-description of a SIMPLE radio circuit which follows, try to draw the SCHEMATIC DIAGRAM. Then check your diagram with figure 94, and see just how confused you were by words. Here goes—

PARTS NEEDED: Two 35Z4 vacuum tubes. One power transformer with step-up ratio of 2–1. Two 16-mf., 600-volt electrolytic condensers. One 50,000-ohm, 5-watt, wire-wound resistor. One 300-ohm, 10-watt, wire-wound resistor.

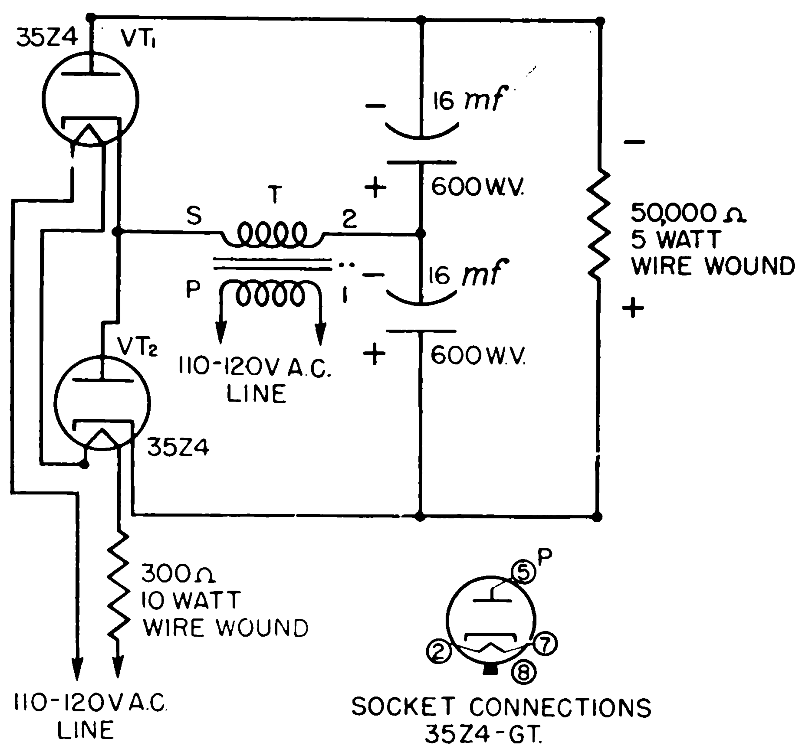


Figure 94.—Voltage-doubler power supply.

PROCEDURE: Connect the cathode, tap 8, of vacuum tube VT_1 to the plate, tap 5, of VT_1. ______ Connect the positive terminal of one electrolytic condenser to the negative terminal of the other electrolytic condenser. ______ Connect the unattached negative terminal of the electrolytic condensers to the plate, tap 5, of VT_1. Connect the unattached positive terminal of the electrolytic condensers to the cathode, tap 8, of VT_2. ______ Connect one end of the bleeder resistor to the plate of VT_1 and the other end of the bleeder resistor to the cathode of VT_2.

______ Connect one end of the transformer secondary to the junction between the two electrolytic condensers, and the other end of the transformer secondary to the junction between the plate and cathode of the two vacuum tubes. ______ The primary of the transformer is connected to a 110-120-volt a-c line. ______ Connect the filament, tap 2, of VT_1, in series with the filament, tap 7, of VT_2. ______ Connect one end of the 3,000-ohm resistor to tap 7 of VT_1, and the other end of this resistor to one side of a 110-120 volt a-c line. ______ Connect tap 2 of VT_2 to the other end of the a-c line. ______ Turn on the a-c voltages, and your voltage-doubler power supply is ready to work. ______ The plate end of the 50,000 ohm resistor is the negative terminal, and the opposite end is the positive terminal.

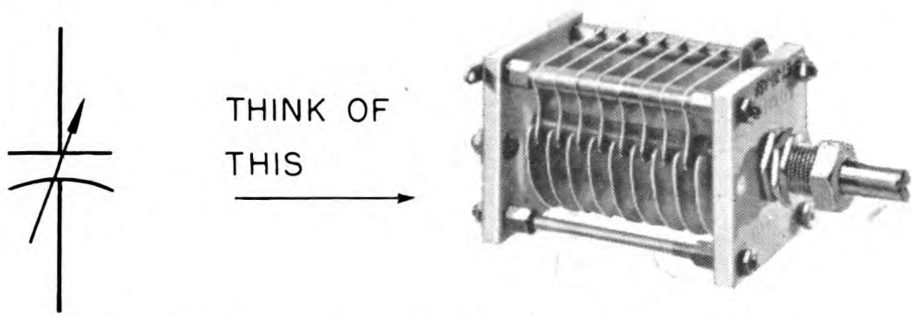


Figure 95.—Schematic symbol and the equivalent condenser.

This was the word description for a SIMPLE circuit! Imagine the word description for a RBB receiver or a TBL transmitter!

By reading the schematic diagram, you can get directions for wiring a radio circuit, find out what KIND of circuit you have, and HOW the circuit works. A schematic helps you service and repair the transmitter or receiver by indicating WHERE the parts are and where trouble may be likely to appear.

STANDARD SCHEMATIC SYMBOLS

In spite of the many attempts to standardize the schematic symbols used with radio circuits, there are still variations in some of the symbols used by the Navy, equipment manufacturers, and text-book publishing companies.

BuShips has developed a new list of standard Navy radio symbols which you will find on page 247 of this

manual. This list and the manufacturer's lists are identical for most parts, but since there are some exceptions, both Navy and manufacturer symbols are shown.

READING A SCHEMATIC DIAGRAM

In addition to learning the symbols, learn how they FIT together in a schematic diagram. Be able to associate the symbols with the actual parts as illustrated in figure 95.

Figure 96 is a combination illustration-and-schematic diagram of a simple receiver. The drawings around the border shows what each part actually looks like as you can see it mounted on the chassis of a radio. Many times the parts are hidden by shields, wires, or by other parts and will be difficult to find and identify. Keep at it! With practice you will overcome that difficulty.

Here's a tip—The easiest way to identify the parts of a circuit is to first hunt out the VACUUM TUBES. Their TYPE NUMBERS are marked on the diagram and on the tubes. After you have picked out the tubes, use the color code and other markings on the RESISTORS and CONDENSERS to guide you in finding the other parts.

Up to now, you have not studied any vacuum tubes in this text. As you know many types of tubes are needed to make an efficient radio. Even though you don't know what makes them work, you should know their first names and how to identify them in the schematic diagrams.

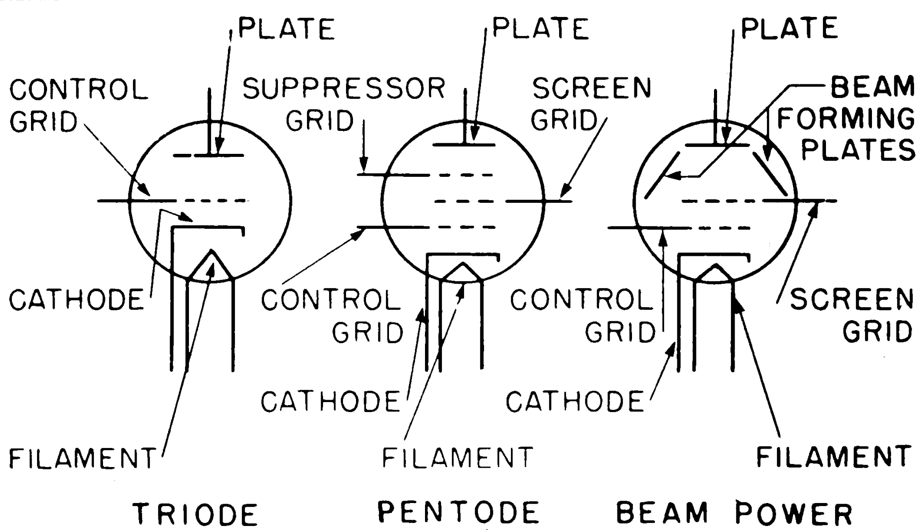
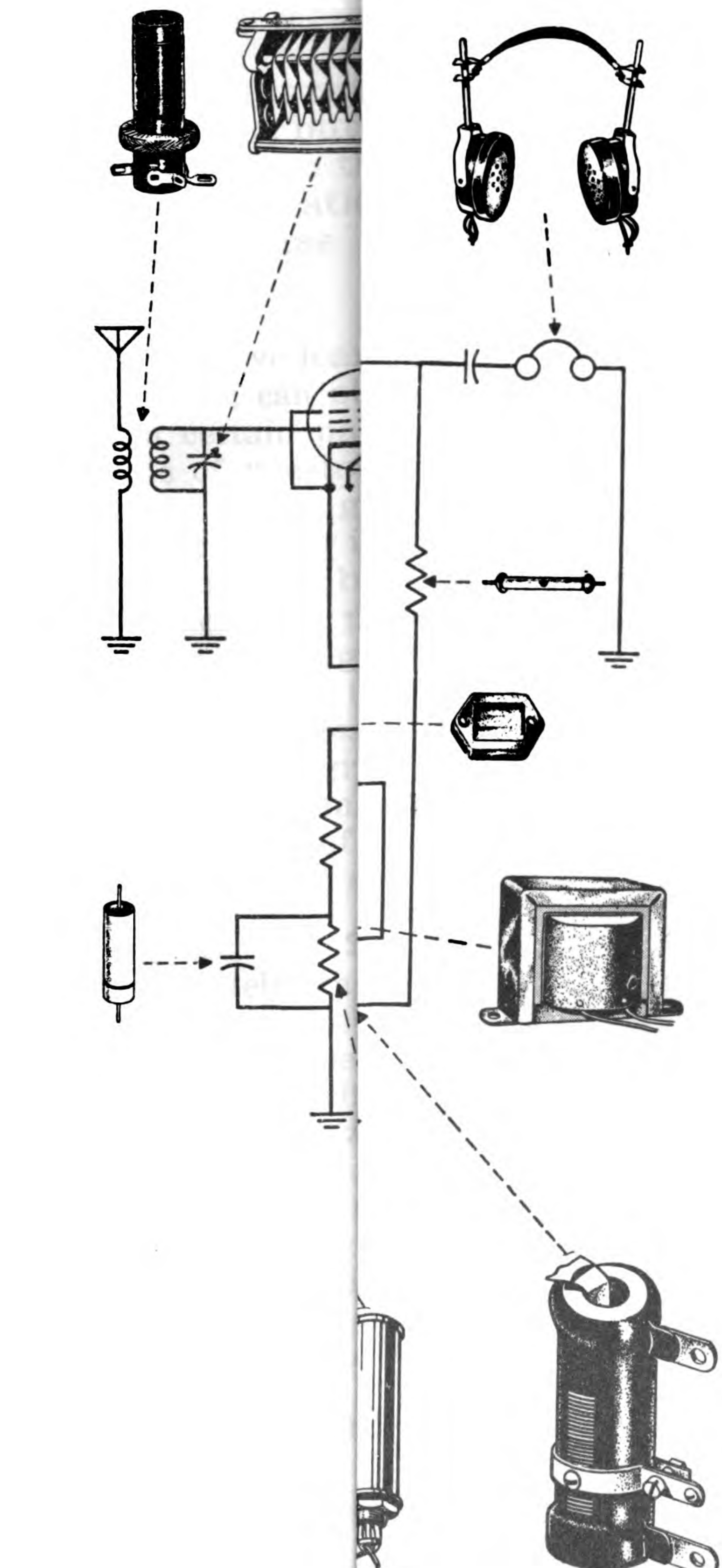


Figure 97.—Triode, pentode, and beam-power vacuum tube symbols.

Figure 97 shows the symbols for three basic amplifier



tubes. Learn the symbols and the names of the elements so you will be able to recognize these tubes in any schematic diagram. There are many other types of vacuum tubes, but most of them are combinations of the diodes and these three types.

More information on amplifier tubes is given in the Training Course for Electronic Technician's Mate 2c, Volume I.

CIRCUIT TRACING

Once you've learned to identify the various parts in a circuit, you can start doing the CIRCUIT TRACING. Start with a certain part and then trace through the actual circuits of resistors and condensers, from one stage to another, following the schematic diagram.

Circuit tracing is the basis for TROUBLE-SHOOTING. You may not always be able to put your finger immediately on the defective part. Sometimes you find it necessary to trace from stage to stage, testing and checking-off the working parts until you arrive at the defective unit.

If the radio gear is unfamiliar to you, you will need a schematic diagram to guide you. Later when the set is familiar, you may be able to trace the circuit by using your knowledge of socket connections, resistor color codes, and wiring color schemes.

SOCKET CONNECTIONS

Fortunately, there are not nearly as many types of SOCKETS as there are vacuum tubes. Figure 98 shows the six major types of sockets used with RECEIVING TUBES. Note the numbering of the prong holes. The sockets are shown as if you were looking at them from beneath the chassis. In all cases, the numbers progress CLOCKWISE. On the 4-prong tube, prong number 1 is the LEFT of the two LARGER prongs. On the 8-to-14-prong socket, type 6, prong number 1 is the first one to the LEFT of the KEY SLOT.

The 4-prong sockets are used almost exclusively for RECTIFIER tubes. The 5-, 6-, and 7-prong sockets were popular around 1930, but are seldom used in modern equipment.

Today, the 8-prong socket is the most common one. Only a few tubes use all eight connections, but the extra contacts are available so that the socket can be used as

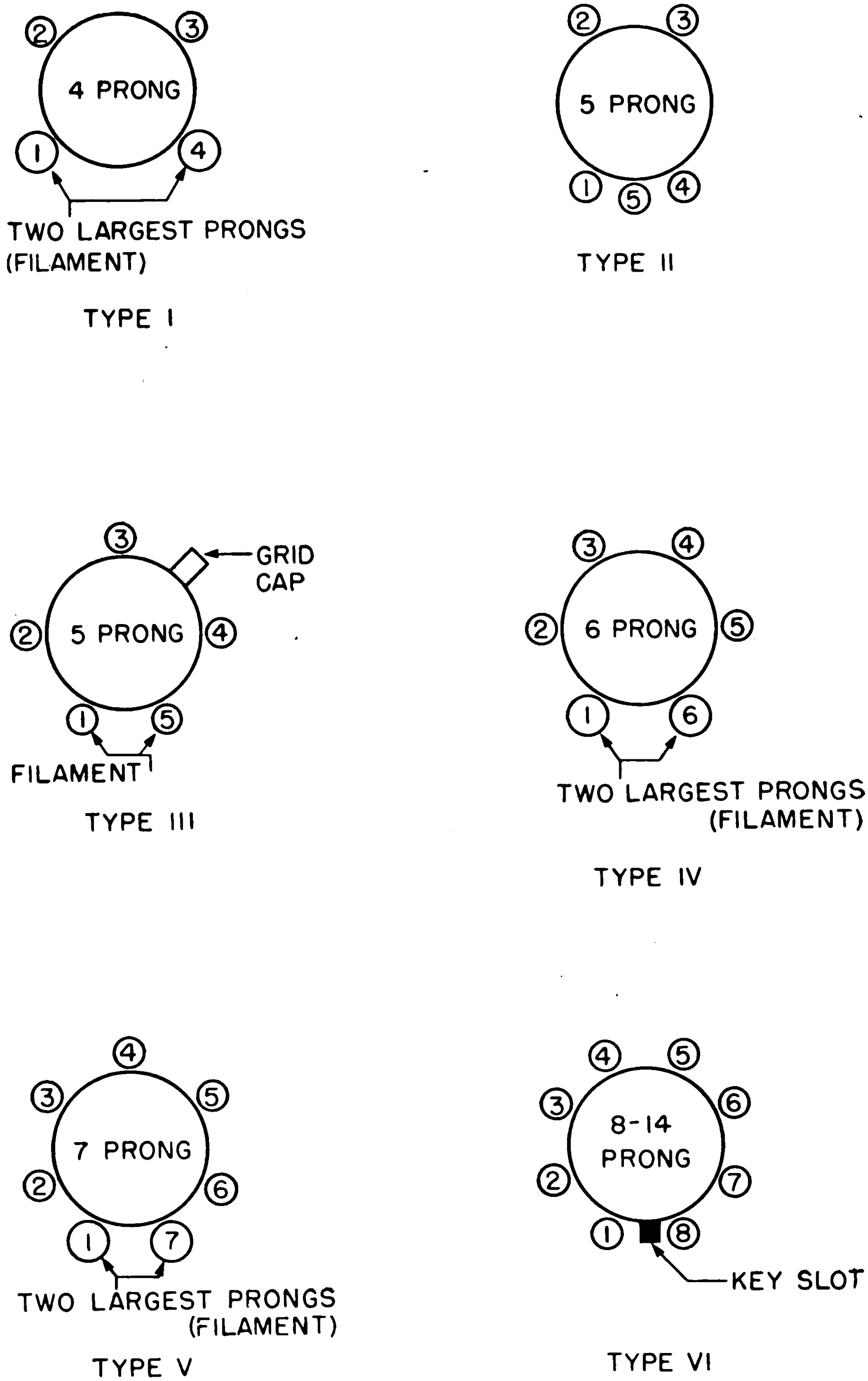


Figure 98.—Receiving tube socket connections, bottom view.

a utility replacement to handle most triodes and pentodes.

The new multi-purpose tubes have as many as 14 prongs. They use a Type 6 socket. The numbering of the contacts is the same as for the 8-prong sockets—clockwise, starting at the key slot.

A GRID CAP CONNECTION is shown in the Type 3 socket. Some of the newer tubes have more than one cap connection. The additional caps are indicated on the diagrams in the same way as a single cap. When you are tracing a circuit which contains tubes with caps, remember that the CAPS ARE ON THE TUBE—not on the socket.

Don't get the idea that every triode, or pentode, uses the SAME PRONGS for the filament, cathode, plate, and other elements. Figure 99 shows the connections for the 6C5 and 6SF5 triodes.

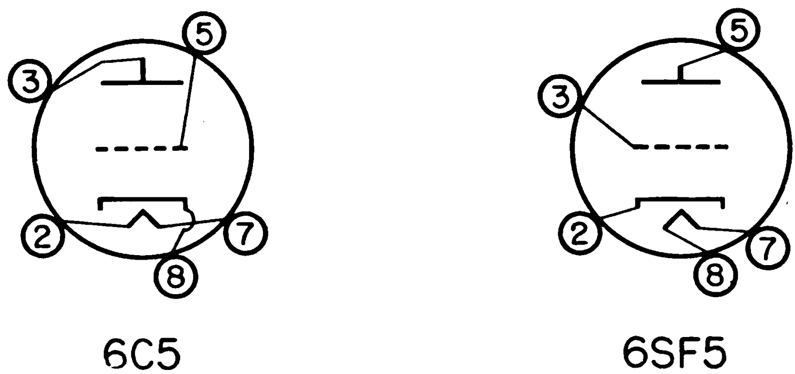


Figure 99.—Socket connections for the 6C5 and 6SF5 triodes.

Some tubes have extra prongs to help hold the tube in a rigid position. These strength prongs, marked *NC* in the vacuum tube manuals, have no internal electrical connection.

Major differences in the shapes and sizes of transmitting tubes require the use of special transmitter-tube sockets. Figure 100 shows ten common types.

Several of the sockets seem to be identical, but slight differences in the size or spacing of the pins make it impossible to place a tube in a socket not designed to take it. Transmitter-tube socket contacts are numbered in the same way as receiving tube sockets.

Transmitting tubes frequently use CAP connections. Some of the v-h-f and u-h-f tubes—such as the 954—use CAPS for ALL the connections. These tubes are usually mounted horizontally, with the grid connection extending out one end of the tube and the plate connection out the other.

WIRE COLOR SCHEMES

Most radio circuits use a standard wire color scheme in wiring the set. This helps you to identify the circuits

and the tube connections. The color code used by the Navy is the same as that used by the Radio Manufacturers Association (RMA).

Figure 101 gives the color code used with POWER TRANSFORMER WINDINGS. Not all power transformers have as many secondary windings as indicated in this figure. Some may have only the high-voltage and the rectifier filament windings. The high-voltage leads are RED. If

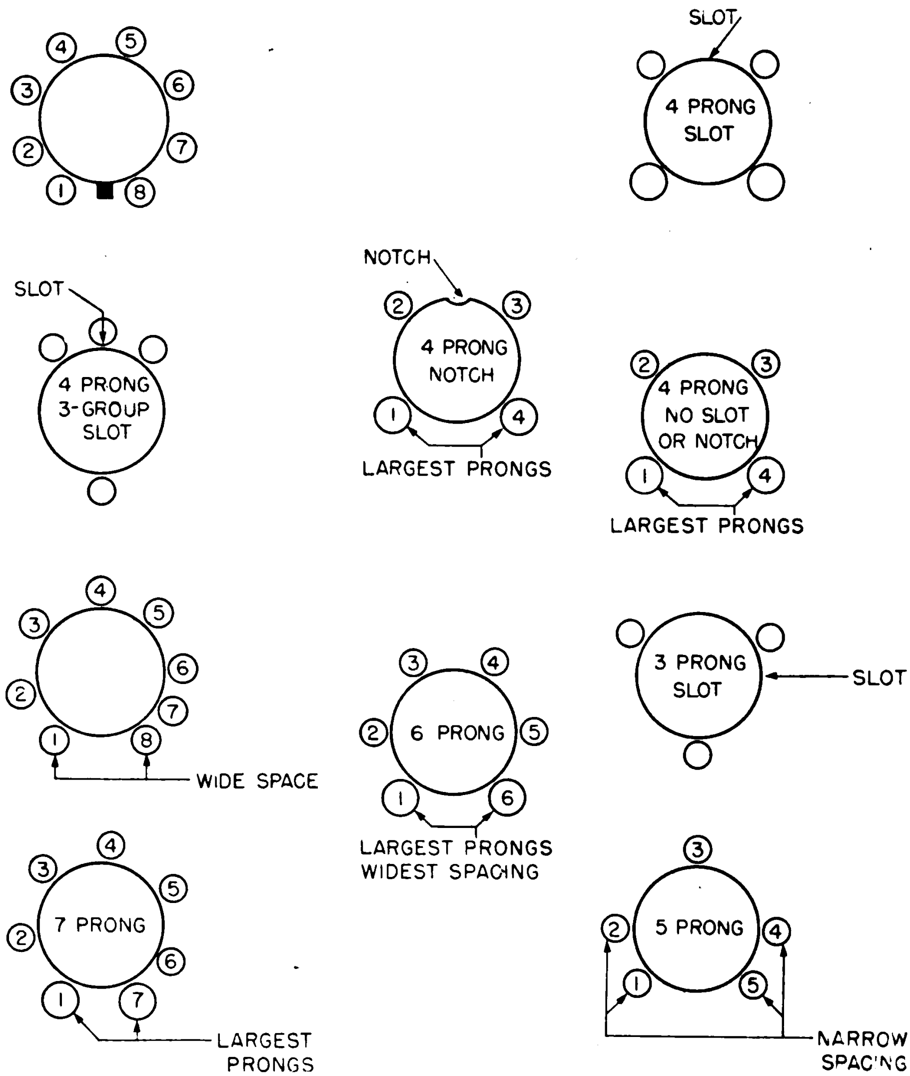


Figure 100.—Transmitter tube socket connector; bottom view.

the high-voltage winding is center-tapped, the lead will be RED-AND-YELLOW. The rectifier filament leads are YELLOW, and the center tap lead will be YELLOW-AND-BLUE.

If the transformer also contains amplifier filament windings, their colors will be as listed in figure 101. Do not confuse the green FILAMENT lead with the green GRID

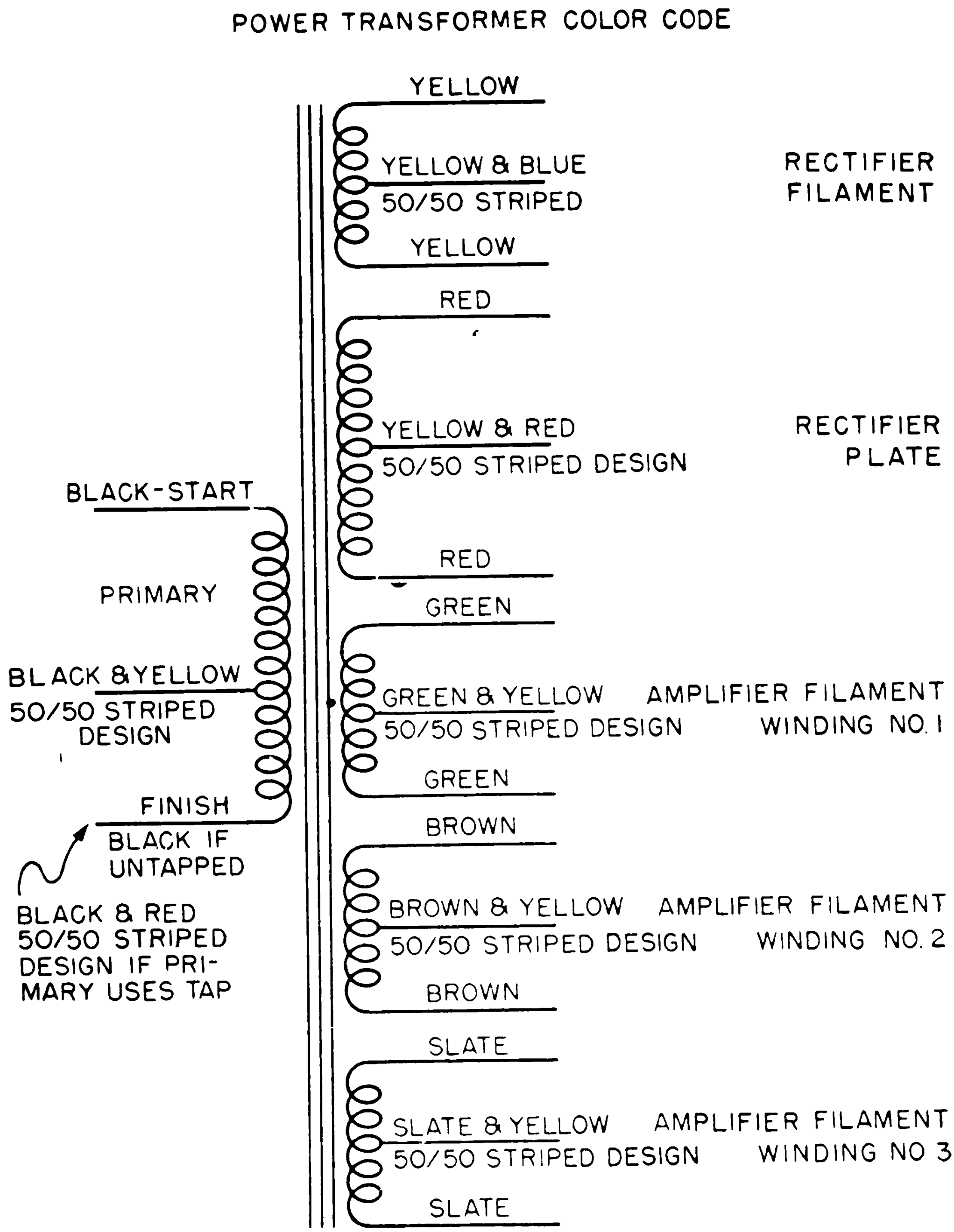


Figure 101.—Power transformer color code.

lead in the I-F and audio transformers. The filament leads are always in pairs, and are twisted. The grid leads are single wires.

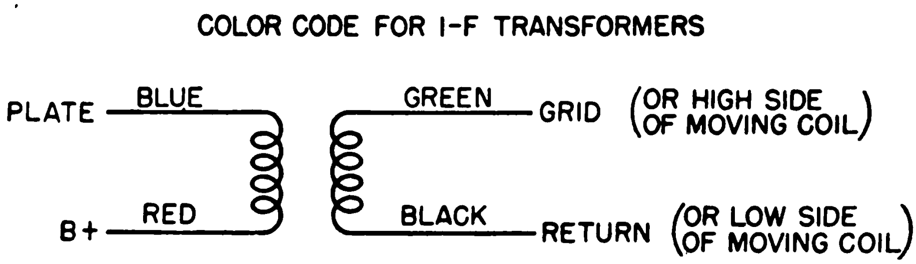


Figure 102.—Intermediate-frequency transformer color code.

Figure 102 gives the color of the leads used with INTERMEDIATE-FREQUENCY transformers. If the vacuum tubes have grid caps, the green grid connection will extend

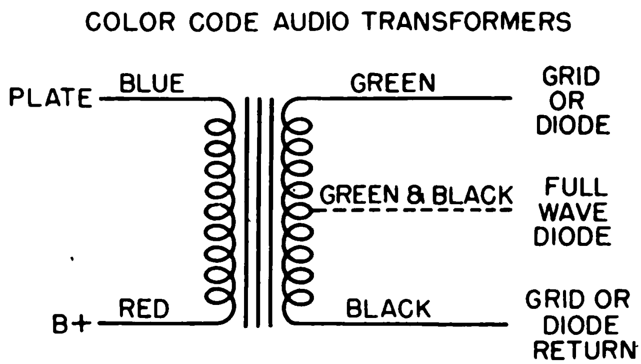


Figure 103.—Audio-frequency transformer color code.

out the TOP of the transformer. The other three leads will be UNDERNEATH the chassis.

The AUDIO-FREQUENCY transformer color code is the

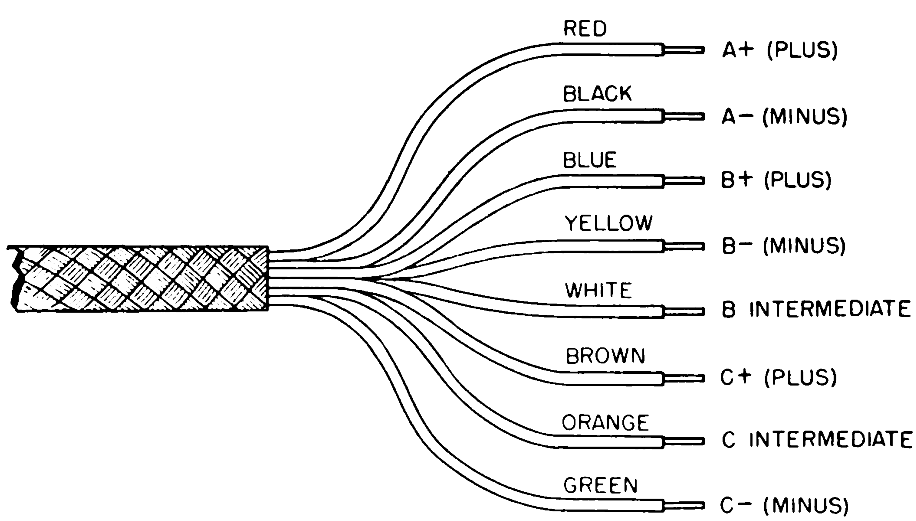
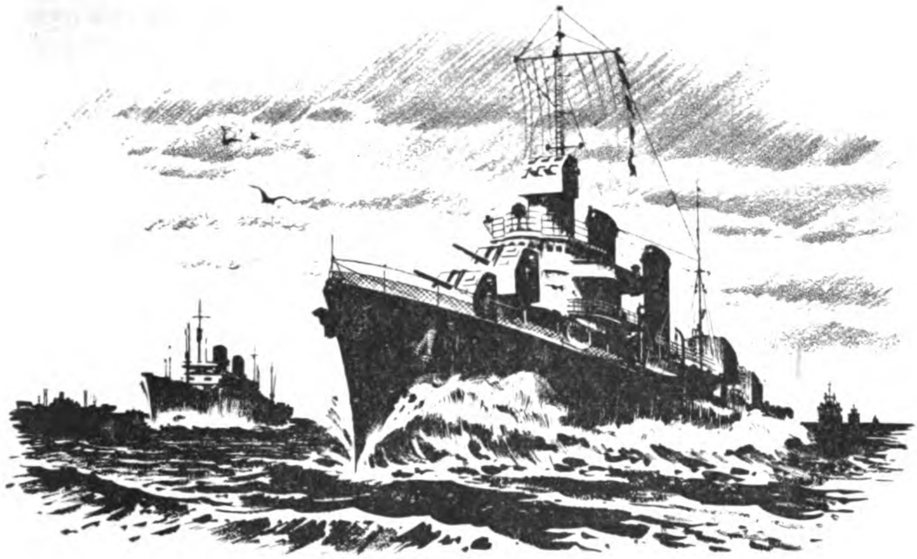


Figure 104.—Battery-cable color code.

same as the code for the I-F transformers. You won't confuse an A-F with an I-F transformer, because the general appearance of the two transformers is quite different. Learn the difference.

Figure 104 gives the color code used with BATTERY cables. SPECIAL cables are used with other circuits. These cables have no standard color, since they are usually part of a special piece of gear. Whenever you find a special color scheme used, the code will usually be explained in the service and maintenance instruction pamphlet that comes with the gear.



CHAPTER 14

THE DIODE—ALADDIN'S LAMP—1945

THE VACUUM TUBE

In 1883, Thomas A. Edison ALMOST discovered how the vacuum tube works. In his experiments with the incandescent light bulb he was troubled by the repeated breaking of the fragile carbon filament. To give the filament more strength, he placed supporting wires alongside—but not touching—the filament. A small piece of insulation provided the bracing link.

One day, Edison attached the POSITIVE terminal of a battery to the supporting wire, and the NEGATIVE battery terminal to the filament circuit. To his surprise, he observed that a CURRENT seemed to be flowing OUT of the bulb through the supporting wire. That wasn't according to the rules, since there was no conductor connecting the filament and the wire. Because he did not understand that current represents the flow of electrons, Edison wrote in his notebook, "When the positive terminal of a battery is connected to the supporting wire, a current seems to flow. This is an INTERESTING but WORTHLESS observation."

"Interesting but worthless"? Remember what was said about a carefully prepared record of an experiment that failed? In this case it paid dividends. In 1904, J. Am-

brose Fleming, an English scientist who understood the flow of electrons, started to experiment with Edison's "worthless" observation.

Fleming replaced the supporting wires with a large metal plate. With this new tube he conducted many experiments, the results of which are summed up in the following statements—

FIRST—When a filament is heated red hot, electrons will be given out by the metal and will form a cloud about the filament.

SECOND—When a positive potential is placed upon a metal plate near the filament these electrons will flow from the filament to the plate. By placing larger voltages on the plate, the rate of flow can be increased up to a certain point, beyond which no additional current can be made to flow.

THIRD—If a negative potential is placed upon the plate, no current will flow in either direction.

Because Fleming discovered that current could flow in only ONE direction, the tube was known as "Fleming's Valve." The English still call a vacuum tube a VALVE.

In 1907, American Lee DeForest continued an experiment that had been suggested by Fleming. DeForest placed a screen of fine wires between the filament and the plate. He found that when these wires were made slightly MORE NEGATIVE than the filament, the flow of electrons to the plate was reduced. If the screen was made a little more negative, the flow was reduced still further. And, if the screen was made negative enough, the flow was stopped completely. The wires of this screen were wound on a frame so that they resembled the yard markers on a football field or gridiron. For that reason, this screen is called a GRID.

The use of the grid in a vacuum tube to control the flow of current from the filament to plate is one of the important discoveries by electricians. The grid allowed the vacuum tube to grow up because the presence of the grid permits a feeble voltage to control powerful machines.

You'll study the simple vacuum tubes first and take up the complex types later. Regardless of the number of elements that are included within a single glass envelope, all vacuum tubes go back to the principle discovered in Edison's "worthless observation."

THE DIODE

The vacuum tube discovered by Fleming was a simple two-element device, and after 40 years it's still a useful tube. Nearly every radio has at least one DIODE—two-element vacuum tube. A high-power transmitter may have several of them. It is also used in fire-control equipment, public-address systems, industrial devices, and many other places where you want the current to flow in only ONE DIRECTION.

DIRECT-HEATER DIODE

The simple diode has only TWO ELEMENTS—the FILAMENT that is heated white hot and gives off electrons, and the PLATE that attracts the electrons when it is positively charged. The part of the tube that gives off or emits the electrons is the CATHODE, and the part responsible for heating the cathode is the filament. In the simple diode, the cathode and filament are the same. This type of cathode is a DIRECT-HEATER type.

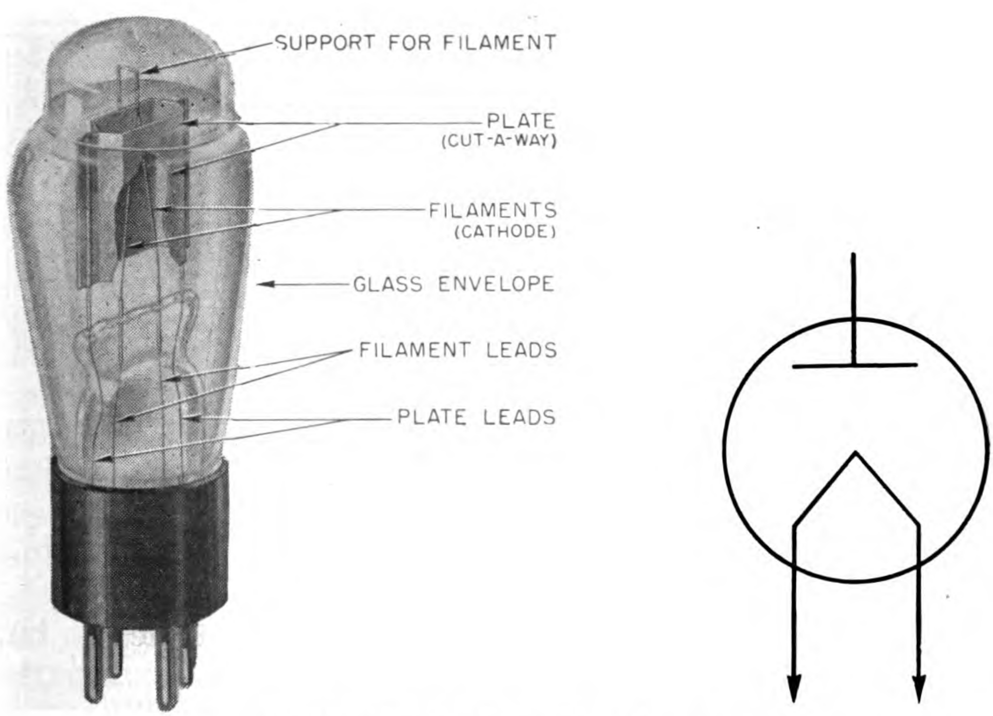


Figure 105.—Simple diode. Direct heater type.

Figure 105 shows a cut-away section and the schematic symbol for a type 81 tube. The plate is a sleeve that surrounds the pyramid-shaped filament. When the filament becomes red hot, electrons will be able to jump

658129°—46—10

clear of the metal and form a cloud around the cathode. This cloud is the SPACE CHARGE.

The electrons in the space charge will move toward the positively-charged plate, and more electrons will come out of the CATHODE—filament—to replace those that have moved to the plate.

INDIRECT-HEATED DIODE

In many circuits, especially those that use a.c. to heat the filaments, the direct-heater cathode produces much objectionable noise. To reduce this noise, the cathode and filament of some diodes are made as TWO separate units.

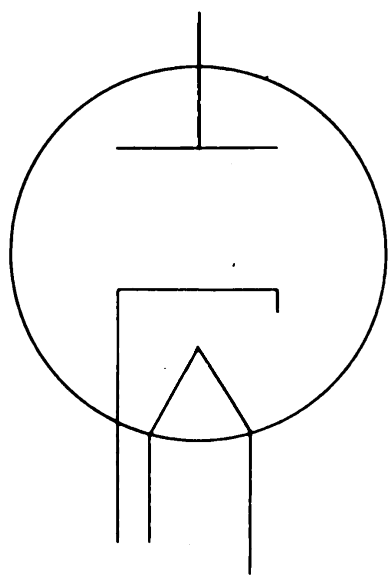


Figure 106.—Simple diode. Indirect-heater type.

Figure 106 shows the schematic symbol for an indirectly-heated diode. The cathode is a METAL SLEEVE with the filament extended up through the center of the sleeve like the heating element in a soldering iron. This is illustrated in figure 107.

Notice that the filament does not touch the sleeve, but is embedded in a material that resembles plaster of paris. This filament is heated with either a.c. or d.c. When the cathode sleeve becomes red-hot, it will give off electrons to form the space charge. The filament is not connected to the cathode in any way, and the cathode alone gives off the electrons. In an indirectly-heated tube, the only function of the filament is to HEAT the cathode.

In many schematic diagrams of radio circuits using indirectly-heated tubes, you'll find the filament omitted from the tube symbols. This is done to simplify the diagram.

WHY ELECTRONS LEAVE HOME

Don't think that a piece of metal is dead and inert. It is a mass of ATOMS. Each atom is a separate little solar system with its ELECTRONS moving about the NUCLEUS. As the atom becomes colder, the movement of the electrons becomes slower. When the atom becomes warmer, the movement of the electrons becomes more violent. When the heat becomes great enough, the movement of electrons will be so rapid that they will have enough energy to JUMP CLEAR of the metal and form a cloud of electrons around the hot metal. This is known as THERMIONIC EMISSION.

Some of the electrons lose their energy and return to the metal, while others are jumping out to take their place in the space charge. Thus for a given temperature, the same number of electrons will leave the metal as return to it. If you wish to increase the number of electrons in the space charge, raise the temperature of the metal.

TYPES OF ELECTRON EMITTERS

Some metals require more heat than others to make the electrons jump clear of the material. Since it takes power to heat the metal cathodes of a vacuum tube, you want to use a material that will give up its electrons easily.

TUNGSTEN was one of the first metals used for cathode emitters. It is one of the FEW metals that can be heated to WHITE heat without burning or oxidizing. The number of FREE ELECTRONS in tungsten is limited, and it takes an extremely high heat to drive them out of the metal. For best operation, a tungsten filament must be operated at a temperature of 4,040° F. or 2,500° Kelvin. Since it takes a lot of current to produce this temperature, the tungsten filament tube is not efficient.

But—in spite of the high operating temperature, tungsten is still used because it is rugged, long-lived, and will stand considerable overloads.

THORIATED tungsten filaments are much more efficient

than pure tungsten. The thoriated type will give great emission at 2,961° F. or 1,900° K. The lower temperature provides greater electrical economy.

This type of filament or EMITTER is produced by coating a tungsten filament with a mixture of THORIUM OXIDE and CARBON. After evacuation and sealing, the tube is given a heat treatment which leaves a thin coat of METALLIC THORIUM on the tungsten filament or cathode. By this arrangement, the filament has the high physical strength of tungsten and the high emission rate of thorium.

This type of emitter has another valuable property—it can be REJUVENATED. After the tube has been used for a long time, you "boil out" the thorium by over-heating it for a few minutes. The tube then is practically as good

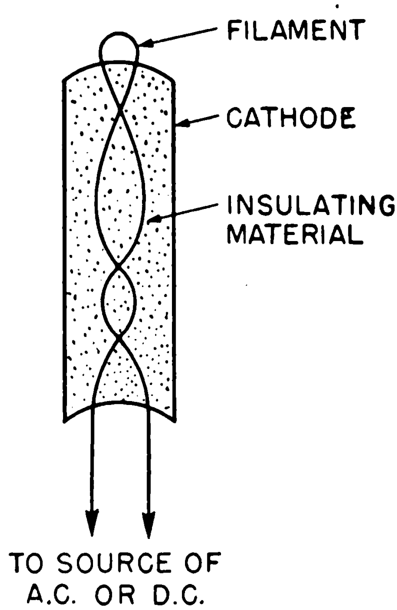


Figure 107.—Indirectly-heated cathode.

as new. The renewing process may be repeated several times with good results.

The OXIDE-COATED filaments are the most efficient for use in small, low-power transmitters and receivers. The filament or cathode is usually formed from NICKEL ALLOY and is coated with a thin coat of BARIUM oxide or STRONTIUM oxides.

The chief advantage to using this type of emitter is the low operating temperature of about 1,611° F. or 1,150° K. This saving in power is important in small radio sets.

RIVER OF ELECTRONS FROM CATHODE TO PLATE

You remember that electrons will flow from the space charge around the cathode to the plate when the plate is POSITIVE. This stream of electrons produces the PLATE CURRENT. In the standard abbreviations for radio terms, the PLATE is indicated by *P* or *p*, and the CATHODE is indicated by the letter *K* or *k*. By making a combination of *p* and *I* for CURRENT, you get the symbol I_p for the plate current that is flowing from the cathode to the plate.

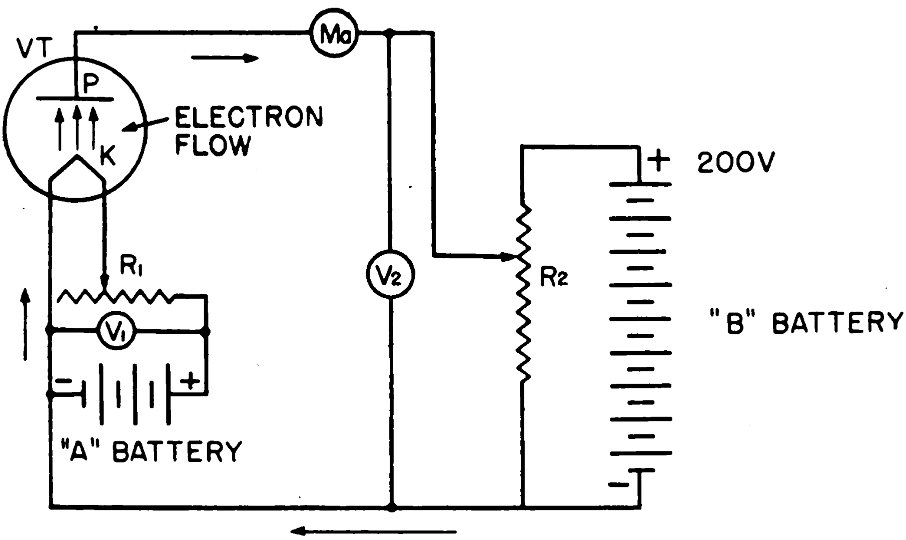


Figure 108.—Circuit for obtaining plate current characteristics of a diode.

The amount of current that will flow to the plate depends largely upon the voltage on the plate. You may measure the plate current flow through a diode with the apparatus of figure 108. The parts are—

VT—Diode with a directly-heated cathode.
P—Plate.
R_1—Rheostat to control the flow of current through the filament.
R_2—Rheostat to control the potential on the plate.
K—Cathode and filament.
V_1—Voltmeter to read the voltage across the filament.
V_2—Voltmeter to read the voltage on the plate.
Ma—Milliammeter to read the current in milliamperes flowing from cathode to plate.
"*A*" Battery—source of voltage to heat the filament.
"*B*" Battery—source of voltage that is applied to the plate.

The first step in this experiment is to turn on the filament voltage and adjust it with rheostat R to a point where the cathode K will glow red. For the initial reading, assume that this potential is 5 volts as indicated by meter V_1.

Next, move the plate-voltage potentiometer down until V_2 reads zero volts. Read the milliammeter. It reads zero milliamps. Next, without changing the filament voltage, move the B-battery potentimeter up until V_2 reads 25 volts. The milliammeter now reads 12 milliamperes. Increase the plate voltage to 50 volts, and you raise the plate current to 23 milliamperes. Continue this process all the way to 200 volts and record the values. You'll get table A below.

TABLE A FILAMENT VOLTAGE = 5 VOLTS		TABLE B FILAMENT VOLTAGE = 6 VOLTS	
PLATE VOLTAGE (E_p)	PLATE CURRENT (I_p)	PLATE VOLTAGE (E_p)	PLATE CURRENT (I_p)
0	0	0	0
25	12	25	12
50	23	50	24
75	30	75	33
100	35	100	39
125	38	125	42
150	39	150	44
175	40	175	45
200	40	200	45

The values of Table A have been plotted as the solid line on the graph below.

Notice that at 150 volts, the solid curve begins to flatten out. Between 175 and 200 volts, the curve is nearly horizontal. If you increase the plate voltage by adding more batteries, the plate current will NOT go up any higher.

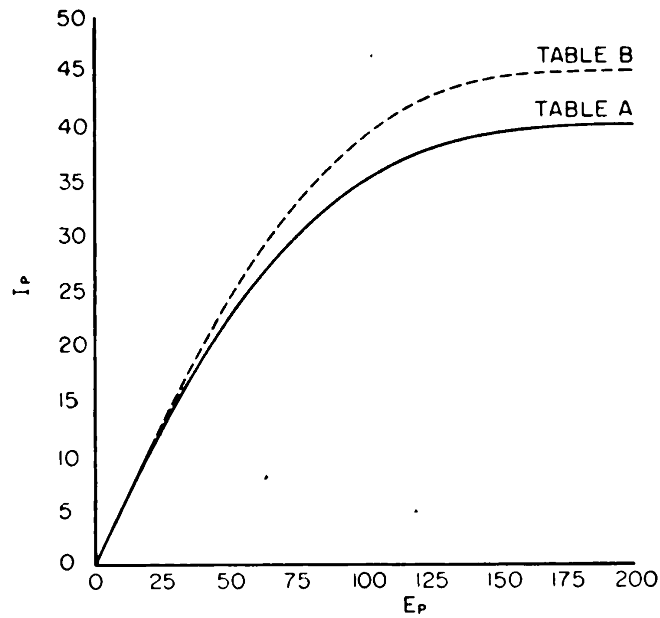
The point beyond which an increase in plate voltage does NOT increase the plate current, is the SATURATION

POINT of the tube. At this point, the plate is taking ALL THE ELECTRONS that the cathode can give off.

But you can increase the flow of electrons to the plate by increasing the temperature of the cathode. On the apparatus of figure 108, turn the rheostat R until the meter V_1 reads 6 volts. Now increase the plate voltage by steps from 0 to 200 volts to get the set of values of Table *B*.

In Table *B*, the plate current is the same as in Table *A* for the steps from 0 to 25 plate volts. But from 25 to 200 volts, all the values of I_p are higher in Table *B* than they are in Table *A*.

In the graph of Table *B*, the broken line shows the



Graph of Tables A and B.

values for the 6-volt filament voltage. At 150 plate volts, the current value is about 44 milliamperes. The flow of current levels off at about 45 milliamperes and will remain constant for all values of higher plate voltage.

The curves of the graph are CHARACTERISTIC curves. The curves in this case are created by increasing the plate voltage, so this particular curve is called a PLATE CHARACTERISTIC CURVE FOR A DIODE. Do not be misled in thinking that the curve above will hold true for ALL diodes. You may not even be able to duplicate it with any two tubes of the same type. But it shows you the method of producing such curves, and what they mean.

THE DIODE

Remember the TURNSTILE at the super market or in the subway? You could push through it to go IN. But when you tried to turn around to come OUT the same way, the turnstile locked, and kept you in. You could move in only one direction.

And that's how a DIODE works—it lets the electrons get over to the PLATE from the CATHODE, but it refuses to let them go back to the cathode.

The diode offers a LOW resistance from the CATHODE to the PLATE, but an extremely HIGH resistance from PLATE to CATHODE. Actually the plate-to-cathode resistance is equal to an OPEN circuit. Therefore, the diode is a UNI-DIRECTIONAL RESISTANCE. Since the diode is used most frequently with a.c., the resistance is called unidirectional IMPEDANCE. The diode is also called a RECTIFIER.

THE DIODE AS A RECTIFIER

One of the most useful applications of the diode is to CHANGE A.C. INTO D.C. Motor-generator units and other mechanical devices have been developed for this job, but for small amounts of power, none of them has the efficiency and convenience of the diode.

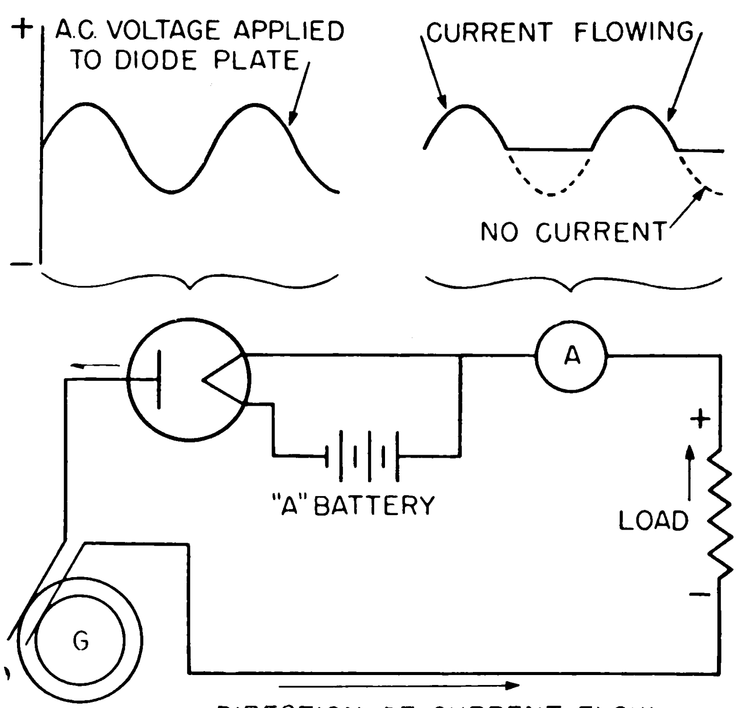


Figure 109.—The diode used as a rectifier.

The circuit for a diode rectifier is simple. In figure 109, a diode is inserted in the a-c line. This arrangement will cause the diode to offer a low resistance in one direction and a resistance equal to an open circuit in the other.

On the half-cycle when the plate is POSITIVE, the current will flow from the cathode to the plate. On the half-cycle when the plate is NEGATIVE, no current will flow through the tube. But on the next half-cycle, when the plate is again positive, the tube will again conduct current.

Thus the current flow through the load *L* will be a pattern of the POSITIVE HALF-CYCLE that is applied to the plate, but will cease to flow on the NEGATIVE HALF-CYCLE.

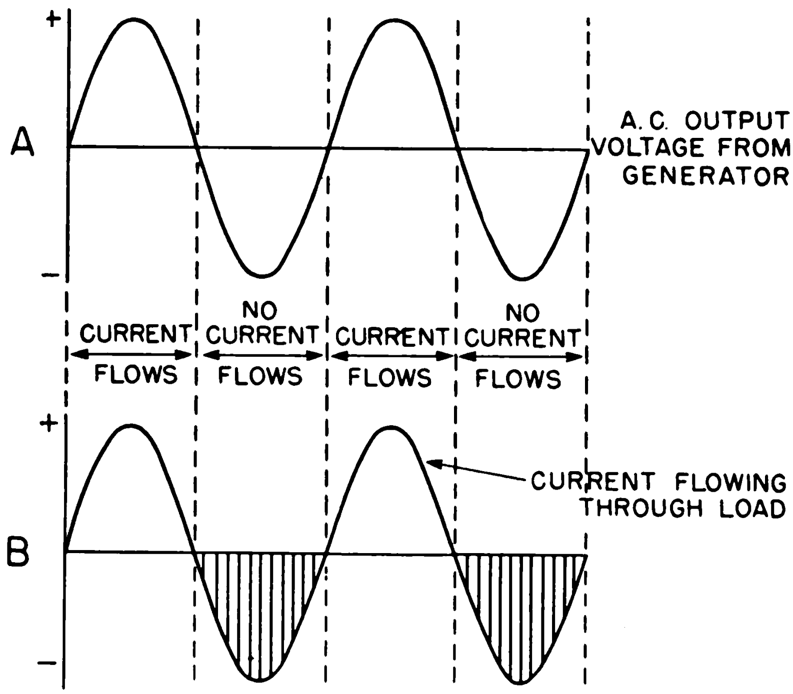
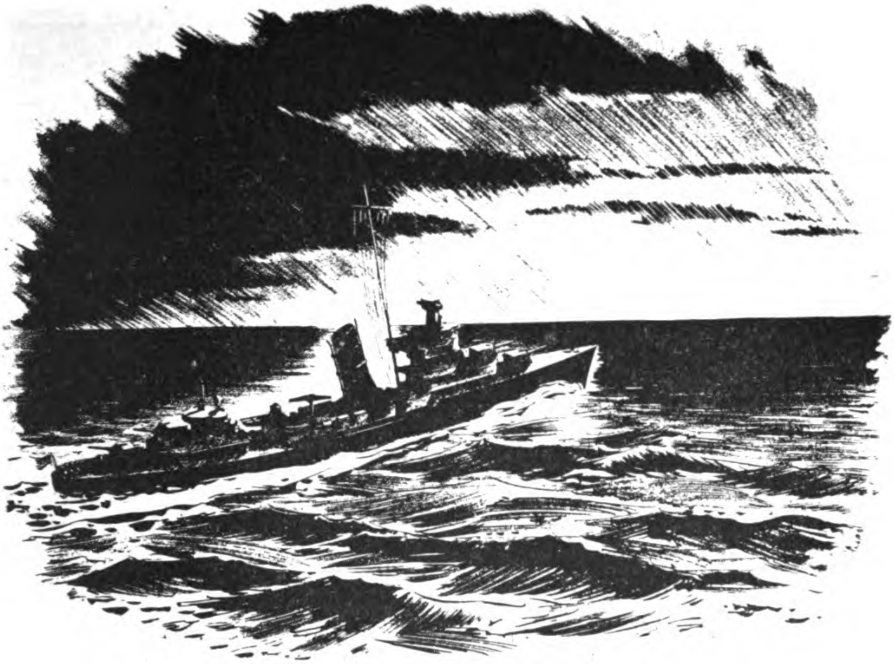


Figure 110.—Applied a-c voltage and current flowing through a diode.

Figure 110 shows this relationship of the a-c voltage applied to the plate of the diode, and the current flowing through the tube. Notice that you're using the POSITIVE half-cycles. You are actually WASTING all the NEGATIVE half-cycle; but you have succeeded in causing the current to flow in only ONE DIRECTION through the load.

A diode that causes the current to flow in only one direction is called a RECTIFIER. In the next chapter, you will discover some of the common applications of the rectifier principle.



CHAPTER 15

POWER SUPPLIES

PUTTING THE DIODE TO WORK

Unless you sport a couple of hash marks, you probably don't remember the "good old days" when Pop had that battery-powered radio in the living room. Mom was always hopping mad about the acid holes in the rug and Pop was always swearing because the automobile storage battery he used for "A" power managed to lie down and play dead right in the middle of his favorite program.

Now Pop and Mom have no worries—at least none about the A-battery. It's been replaced by the clean, efficient, long-lived POWER TUBE—a diode that converts 110 a.c. to d.c. for powering the radio. You'll find A-batteries used today only in portable radios.

WHAT MAKES A POWER SUPPLY?

The typical power supply is made up of THREE major units. They are—TRANSFORMER, RECTIFIER, and FILTER. You already know the action of each of these parts; all you need to do now is put them together.

Figure 111 is a diagram of a simple half-wave power supply showing how the three parts are connected to-

gether. The input to the transformer is a.c. and the output is a STEADY d.c.

WHY USE A TRANSFORMER?

You already know that a transformer is used to step the voltage either UP or DOWN. And that is why you use the transformer here. You wish to step the voltage UP for the PLATE supply and DOWN for the FILAMENT circuit.

The ordinary radio receiver uses PLATE VOLTAGES higher than 200 volts. Many pieces of electronic equipment aboard ship will use d-c potentials of several thousand volts. Thus you can see that a line voltage of 110

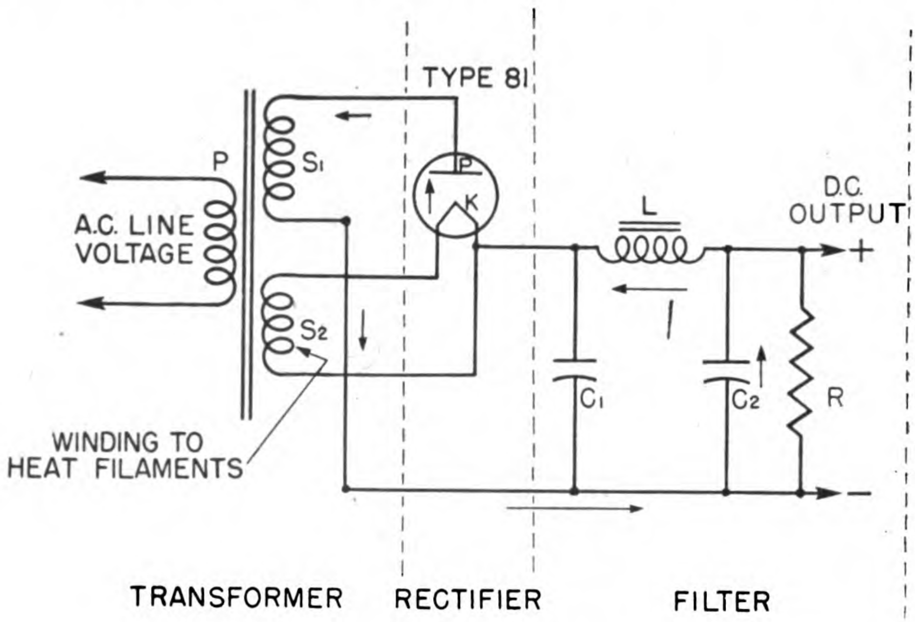


Figure 111.—Power supply using half-wave rectifier.

volts a.c. won't do you any good unless a STEP-UP TRANSFORMER is used.

The filaments in the vacuum tubes require a LARGE CURRENT at a LOW VOLTAGE. In most tubes, an a.c. of 6 to 12 volts is sufficient to provide the heat necessary to cause the cathodes to give off electrons. Therefore, you'll need a step-down transformer to reduce the line voltage to this lower value.

Large power supplies used with TRANSMITTERS have separate transformers to STEP-UP the voltage for the PLATE circuits, and other transformers REDUCE the voltage for the FILAMENT circuits. Small transmitters and most receivers have only one transformer to do both jobs.

Separate windings are placed on the secondary so that both stepped-up and stepped-down voltages can be obtained from the secondary.

A dual-purpose transformer of this type is shown in figure 111. The secondary S_1 is the HIGH-VOLTAGE winding to supply the plate circuits. The secondary S_2 is the LOW-VOLTAGE winding which supplies the current to heat the filaments. For example—the high-voltage secondary S_1 may deliver an a-c voltage of 400 volts, while the low-voltage secondary S_2 has a 5-volt a-c output.

THE RECTIFIER TUBE

The rectifier tube is a diode of the type that you already know. It is a direct-heater diode, since the filament does double-duty as the cathode. As you already know, the job of the rectifier is to allow the current flow in only ONE DIRECTION.

FILTERING THE BUMPS OUT OF D.C.

The FILTER is the LOW-PASS type you read about in chapter 12. This filter permits only smooth and steady direct current to flow out to the radio circuit. Condenser C_1 is connected directly across the CATHODE to GROUND. This type of filter has the condenser connection BETWEEN the cathode and the choke, and is a CONDENSER INPUT FILTER. You will also call it a "pi section filter" because in schematic diagrams it looks like the Greek letter π (pi, pronounced *pie*).

At the left-hand side of figure 112, you apply a potential of 110 volts a.c. to the primary S of the transformer. This voltage is stepped up to 400 volts a.c. at the secondary. When the TOP terminal of the transformer is POSITIVE, current will flow from the cathode to the positive plate. This current then flows out through the LOWER terminal of the transformer, up through the bleeder resistor R, and back to the cathode through the choke coil L.

ACTION OF THE DIODE

Since the diode is able to conduct current only when the plate is POSITIVE with respect to the cathode, current will flow only during the positive half-cycle, and will not flow during the NEGATIVE half-cycle. The negative half of the alternation is blotted out and wasted.

The voltage delivered to the FILTER SECTION of the power supply is a PULSATING d.c. that starts at ZERO, rises to maximum, and drops back down to zero again. All the time that the plate is NEGATIVE, the d-c voltage is zero. When the plate once more becomes POSITIVE, another pulse of d-c voltage is created.

SMOOTHING OUT THE D.C.

You use condensers in the circuit to prevent the pulsating d.c. from rising TOO HIGH or from falling to ZERO. Here is how it is done—

When the plate is positive and the tube is conducting current, the condenser will CHARGE RAPIDLY almost to the PEAK VALUE of the pulsating d.c. When the negative cycle comes along, the condenser discharges by drawing electrons up through the BLEEDER resistor to take the place of those that left the cathode and traveled to the plate. In this way, the condenser maintains the current flow in the bleeder circuit EVEN WHEN THE TUBE IS NOT CONDUCTING CURRENT.

In other words, this condenser acts as an AUXILIARY PUMP that will continue to pump electrons even after the MAIN PUMP—the rectifier tube—has ceased to operate.

In figure 112, you see that condenser C_1 has the ability to fill in the gaps between the successive positive pulses. Also notice that although the voltage is all d.c. it is not perfectly smooth, but has a small amount of RIPPLE. The amount of this ripple depends upon the type of tube used, the current being drained from the circuit, and the values of the condensers and choke being used.

THE CHOKE—A SPONGE

For a FULL explanation of the part played by the choke coil in removing the wrinkles from d.c., you'd get into a complicated mathematical snarl. But the following two points will give you a simple picture of why a choke coil is placed in the circuit.

FIRST—In any circuit that contains a ripple voltage, the ripple will either be DISTRIBUTED THROUGHOUT THE ENTIRE CIRCUIT or CONCENTRATED at one point. Since you do not want the ripple to appear across the bleeder resistor, you will insert a CHOKE COIL to absorb as much

of the ripple as possible. The choke acts like a sponge and SOAKS UP the ripple voltage.

SECOND—A well-known principle about INDUCTANCES: when the voltage of the pulsating d.c. is rising, the FIELD surrounding the choke coil is expanding. When the voltage starts to fall, the field of the choke will collapse, and tend to keep the current flowing in the ORIGINAL direction. Ever hear that before? Sure you have.

You now have two forces—the condenser and the choke coil—tending to keep the current flowing in the circuit in the same direction and at a constant value.

THE SECOND CONDENSER

By now, you've beaten the humps in the d.c. pretty well down, but a small amount of ripple may have sneaked past the choke coil. The second condenser acts as a second auxiliary pump to help the first condenser and choke coil iron out the wrinkles that are left.

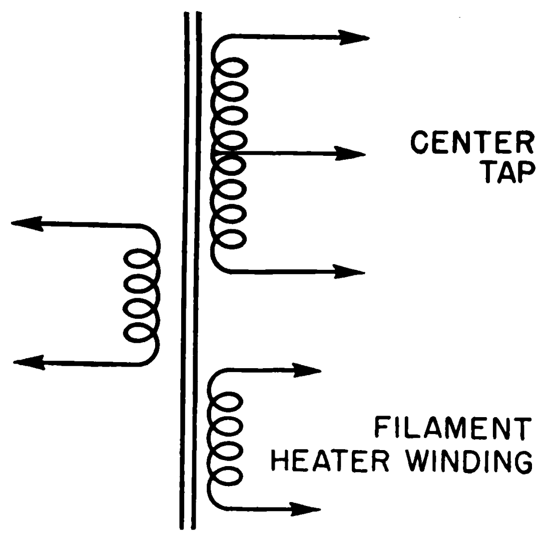


Figure 113.—Center-tapped transformer for a full-wave rectifier.

In figure 112, the voltage is almost smooth d.c. by the time the second condenser has finished its job. The voltage that appears across the BLEEDER is a d.c. with almost no ripple.

FULL-WAVE RECTIFIER

Most people are not "tight," but they do like to get their money's worth. The "one-lung" half-wave rectifier is an example of a none-too-efficient device. It doesn't

give you your money's worth because half of every cycle is wasted.

Now to find a way to use the positive AND the negative cycles of each alternation. To do this, it is necessary to change the type of transformer and the construction of the diode. The rest of the power-supply circuit remains the same.

The difference in the transformer used is merely a matter of CENTER-TAPPING the high-voltage secondary.

Notice in figure 113 that a third connection is attached to the center of the high-voltage secondary. The rest of the transformer is the same as the one used with the half-wave rectifier.

THE DUO-DIODE

The new DUO-DIODE tube consists of two diode plates inside one glass envelope. See figure 114. It operates the same as the single diode.

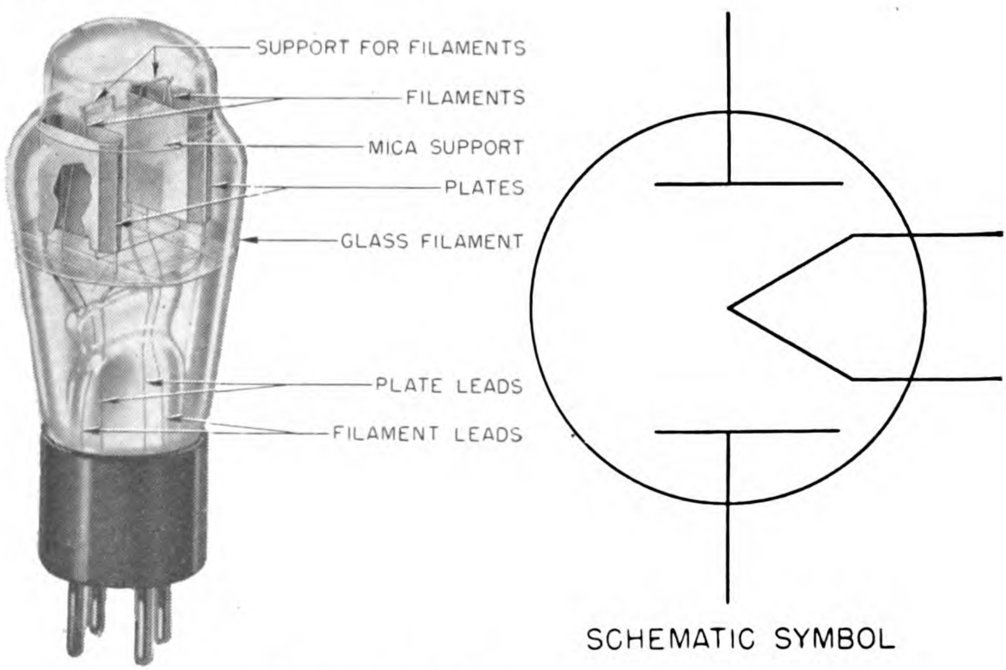


Figure 114.—Duo-diode vacuum tube.

Full-wave rectifiers could use two single diode tubes, but this adds to the cost, and also takes up room. The answer was to place both plates inside of one glass envelope with one long continuous filament. Thus you can see that the new tube is actually the same as having two tubes in one.

THE CIRCUIT

Notice in figure 115 that only two minor changes in connections are present. The CENTER TAP becomes the GROUND connection, and the two END TERMINALS are con-

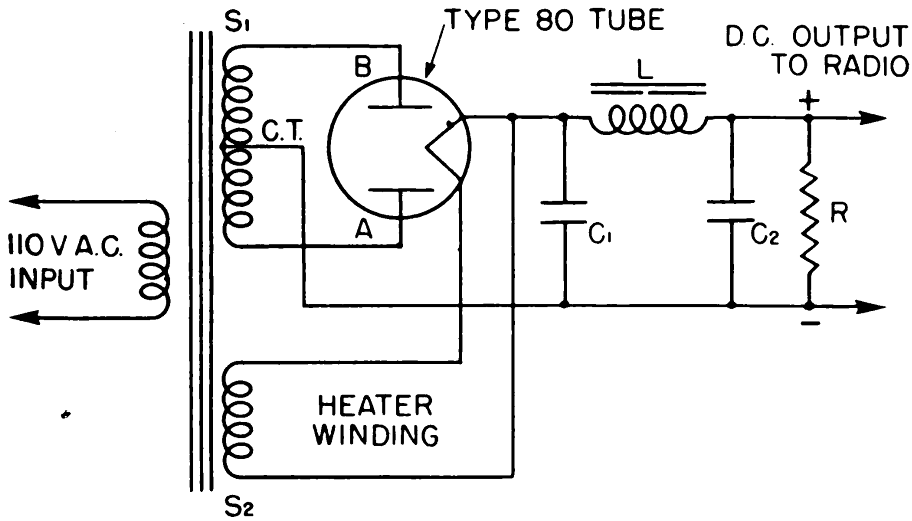


Figure 115.—Circuit for a full-wave rectifier.

nected to the PLATES of the duo-diode. The rest of the circuit is exactly the same as the one used with the half-wave rectifier.

DIRECTION OF CURRENT FLOW

The place to start tracing the direction of the current flow is in the tube. You know that current will flow from the cathode to the positive plates. Since the plates are ALTERNATELY positive and negative, the current will flow FROM THE CATHODE first to one plate and then to the other.

When plate *A* is POSITIVE, current will flow to it, up through the bottom half of the winding, and out at the center tap. When plate *B* is positive, the electrons will flow to it, down through the top half of the transformer winding, and out at the center tap. Thus the current from BOTH plates flows out of the transformer at the center tap.

The points of HIGHEST POTENTIAL are the plates, and the point of LOWEST POTENTIAL is the center tap. Since the electrons are attracted to the point of highest potential, they will flow from the center tap, up through the bleeder and choke to the cathode. From the cathode they

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move to the plate. Thus as you trace the current from the center tap, you are moving toward a higher and higher potential. The HIGHEST POINT in the d-c circuit is the CATHODE, and the LOWEST POINT is the CENTER TAP. Remember this when you are connecting up a power supply. The CENTER TAP is the NEGATIVE terminal and the CATHODE of the vacuum tube is the POSITIVE terminal.

Figure 116 shows how the various elements of the circuit perform their duties in the process of changing a.c. into d.c. Notice how the SECOND PLATE of the rectifier is able to fill in the blank spaces that were left by the half-wave rectifier. Pulse *A* is created when plate *A* is positive, and pulse *B* is caused when plate *B* is positive.

The condenser C_1 performs exactly in the same manner as it did in the half-wave rectifier, except that now there are twice as many CHARGING PULSES. Thus, the discharge time will be HALF AS LONG. Because of this, the ripple will be smaller, and the average d-c voltage will be higher.

The choke, the condenser C_2, and the bleeder will continue to perform their task as they did in the half-wave rectifier. Again, the only difference is that there are now twice as many pulsations.

RIPPLE FREQUENCY

The frequency of most a-c power lines is 60 cycles a second. Each cycle has 60 positive and 60 negative pulsations a second. In a half-wave rectifier, only the 60 positive pulsations are used. Therefore, the RIPPLE FREQUENCY will be 60 cycles a second. How about the full-wave rectifier? With it, you use the positive and the negative pulsations. Hence the ripple frequency of a full-wave rectifier will be 60 positive PLUS 60 negative, or 120 cycles a second. From that illustration you may draw this conclusion:

The ripple frequency in a half-wave rectifier is equal to the line frequency; in a full-wave rectifier it is equal to twice the line frequency.

WHY USE A HALF-WAVE RECTIFIER?

Because of the apparent wastefulness of the half-wave rectifier, you may wonder why you would ever use this type of power supply. Where a HIGH VOLTAGE, but a LOW CURRENT is needed, the half-wave rectifier has an

advantage. An example of such a circuit is the power supply for the electron gun in a cathode-ray tube.

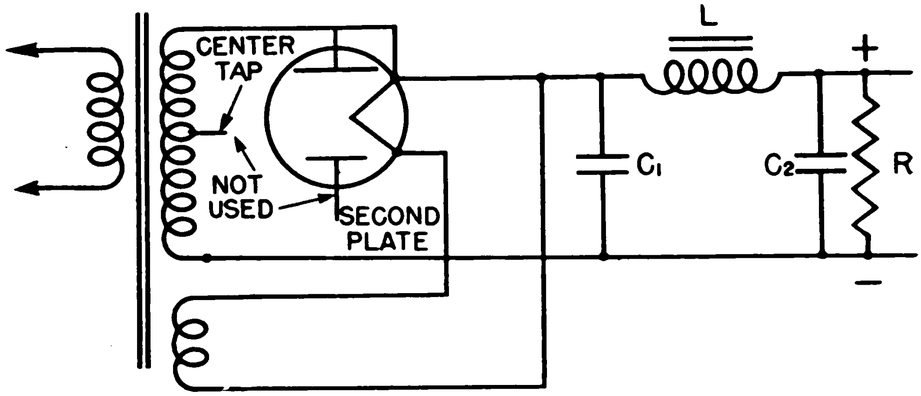


Figure 117.—Method of changing a rectifier from full wave to half-wave to obtain high output voltage with light load.

Notice, in figure 117, that one plate has been disconnected from the transformer. The ground connection of the center tap has been moved down to the former plate connection. To get increased plate area, the FREE PLATE is usually connected directly to the other plate.

The increase in voltage results from the way the transformer is used. Suppose the transformer had an output potential of 400 volts from the center tap to either one of the OUTSIDE terminals. In such a case, the potential BETWEEN the two outside terminals will be 400 + 400, or 800 volts. Where the output d-c potential was only about 350 volts with full-wave rectification, it now will be near 700 volts d-c, using the SAME transformer.

Of course, you could buy a transformer that has an output of 800 volts a.c. on either side of the center tap. The only objection to this would be the increased size and weight of the transformer. So remember, if you wish to have a HIGH D-C VOLTAGE, using a SMALL AMOUNT OF CURRENT, you can get that voltage more readily by using HALF-WAVE RECTIFICATION.

CHOKE INPUT FILTER

The condenser input filter works well with power supplies for small receivers and other electronic equipment that requires only a small amount of current. This type of a filter is not satisfactory for use with power supplies for transmitters because it cannot supply the amount of current necessary.

Figure 118*A* is a choke input filter using a single section of the INVERTED-L-TYPE. Notice that the condenser C_1 has been removed. The removal of this condenser changes the action of the circuit so that the tube is able to conduct more current. The double inverted *L*-type choke input filter in figure 118*B* is the same as 118*A*, but has twice the filtering effect.

To understand why the choke-input filter is able to conduct MORE CURRENT, study the oscillograms in figure 119. To start the comparison, observe the condenser C_1 in the top diagram. Notice that it is connected DIRECTLY from the cathode to ground. Therefore, whatever potential is present across this condenser is also present on the cathode.

CURRENT WITH CONDENSER INPUT FILTER

In figure 119, it is assumed that peak potential applied to the rectifier is 400 volts, and the peak potential to which the condenser is charged is 350 volts. Observe in line *B*, that the peak of the RIPPLE VOLTAGE is 350 volts. Also notice that the MINIMUM ripple voltage across the

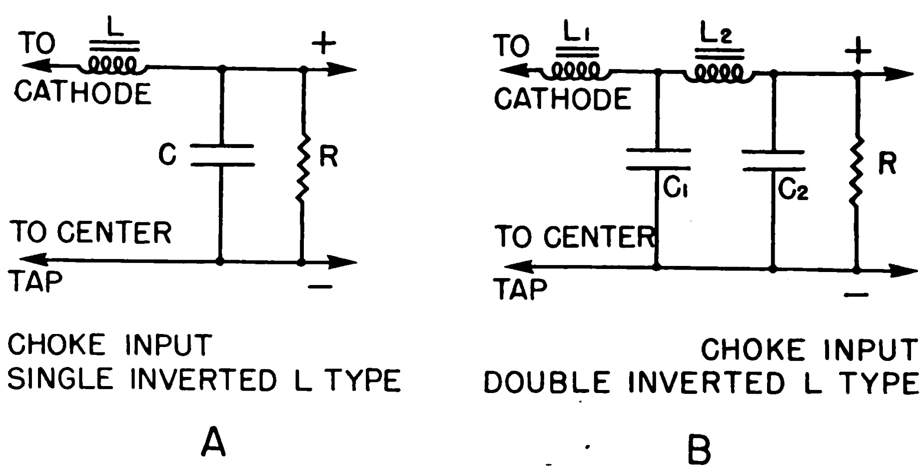


Figure 118.—Choke input filters.

condenser is 300 volts. This will mean that if the minimum potential across the condenser is 300 volts, the minimum CATHODE potential is also 300 volts.

What effect will this have on the flow of current through the tube? First, remember that electrons will not flow to the plate unless the plate is MORE POSITIVE than the cathode. What is the minimum positive cathode potential? It is 300 volts. When will current begin to

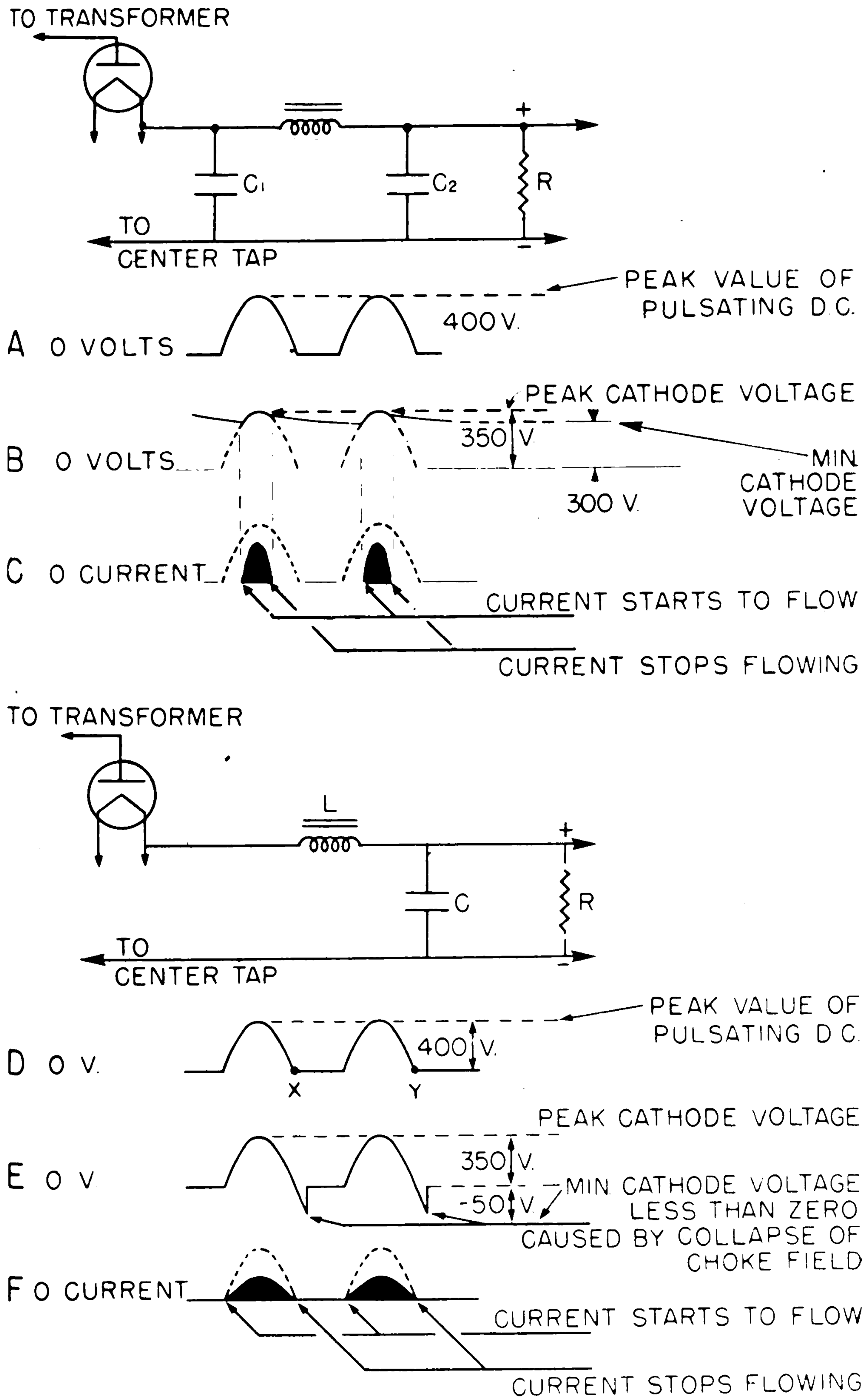


Figure 119.—Comparison of current flow in a condenser and a choke-input filter.

flow? As soon as the plate has reached a potential GREATER THAN 300 volts.

Now look at the plate. Its potential comes from the transformer. This voltage starts at zero and rises gradually to 400 volts. From that you may see, that for ALL POTENTIALS between 0 and 300 volts, no electrons will be able to flow to the plate because the cathode is more positive than the plate. Therefore, current will not start to flow until a considerable portion of the sine wave of voltage has passed. Any plate voltage greater than 300 volts will cause the plate current to flow. The upward swing may be divided as shown in figure 120.

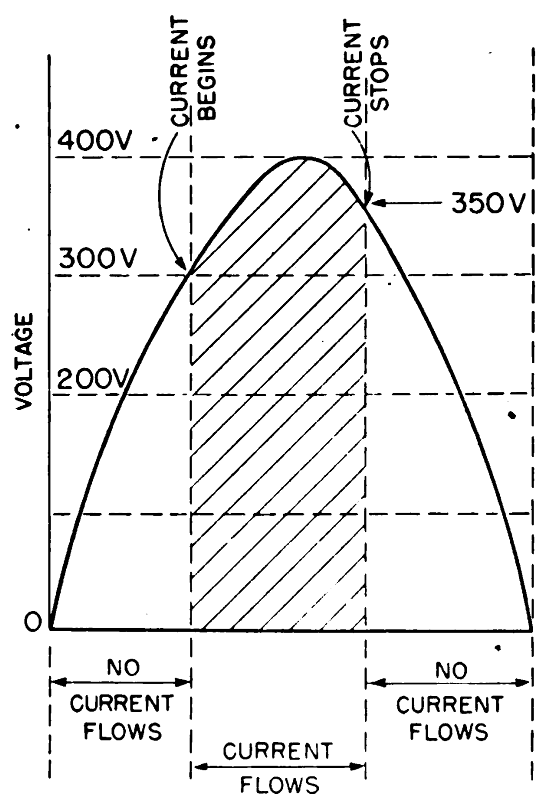


Figure 120.—Current flow with condenser input filter.

How about the downward swing of the plate voltage? By this time, the condenser has charged to a peak value of 350 volts. This means that the cathode is also at a potential of 350 volts. Applying the same rule—current will not flow to the plate after the plate potential becomes less than 350 volts.

To SUMMARIZE these points—look at figure 120. With a condenser input filter, current will flow for considerably less than half the time, because the cathode is always at

a potential greater than zero. Also observe the same relationship points in lines B and C in figure 120.

CURRENT WITH A CHOKE INPUT FILTER

By studying line E, figure 119, you can see why the CHOKE changes the behavior of the circuit. Remember that a choke is an inductive device. When current ceases to flow through it EVEN FOR AN INSTANT, the field will COLLAPSE. In line D at points X and Y, the voltage applied

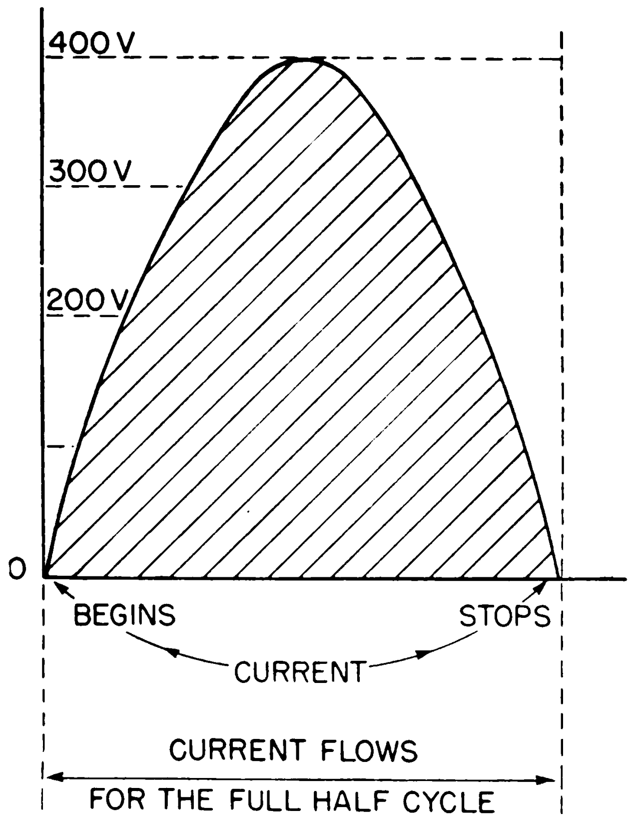


Figure 121.—Current-voltage relationship with choke input filter.

to the plate is ZERO. Normally, that would mean that the current has ceased to flow.

But at the instant the current would cease flowing, the field of the choke coil collapses and drives the CATHODE POTENTIAL to a value LESS THAN ZERO. In line E this is indicated by the downward dip of voltage to —50 volts. Here's the importance of this abrupt drop in voltage: any value of cathode voltage less than zero will permit current to start flowing the instant the plate becomes more positive than the cathode. Therefore, with a CHOKE INPUT FILTER, current will flow during the ENTIRE HALF

CYCLE. Thus, in a voltage swing of 0 to 400 volts, current will flow the full 180° of the positive cycle. Figure 121 shows the relationship of applied voltage and plate current flowing through the rectifier using a choke input filter.

What is true of the half-wave rectifier is also true of a full-wave rectifier. If the choke and condenser of choke input filter are made large enough, the current in the external circuit will be almost steady and continuous.

CONDENSER vs. CHOKE-INPUT FILTERS

The type of filter that you will select will depend largely upon what you intend to use the power supply for. No definite rule can be given, but the following table will help you understand the merits of each type of filter.

CONDENSER INPUT FILTER	CHOKE INPUT FILTER
1. Use with LIGHT LOADS such as receivers.	1. Use with HEAVY LOADS, such as transmitters and speech amplifier systems.
2. It has a higher average output voltage.	2. It has a lower average output voltage than the condenser input filter.
3. Regulation is poor.	3. Has good voltage regulation.
4. Used most commonly with high-vacuum rectifier tubes.	4. Usually used with gas-rectifier tubes.

CHOOSING THE PARTS FOR A POWER SUPPLY

Sometime you may need to assemble a power supply from scratch. Then you will need to know some of the pitfalls to be avoided in selecting the parts. If you do not take these points into consideration, you may find that the power supply you built fails to give the desired voltage, or it may even burn out.

SELECTING THE TRANSFORMER

Two points are important in your selection of a transformer—it must deliver the DESIRED VOLTAGE, and it must be able to carry the REQUIRED CURRENT without burning out.

You have known for a long time that any piece of electrical equipment which is forced to carry more cur-

rent than its rated value will soon burn out. And you cannot ignore that fact in selecting power transformers.

You also know that if a transformer is operating at PEAK CAPACITY, its life will be shortened. When you select a transformer be sure that it is able to supply the necessary amount of current, PLUS A MARGIN FOR SAFETY. Just how large that margin should be cannot be definitely given, but it is a good practice to allow at least 100 percent extra. If the circuit is expected to supply a continuous current of 400 Ma, take 100 percent of this amount and add it to the 400 Ma. A safe value will be—

$$400 + 400 = 800 \text{ Ma.}$$

Not only will the transformer last longer, but the differences in the d-c voltage output between light and heavy loads will be less if the transformer is capable of delivering a larger amount of current than it is called upon to supply.

The choice of the transformer with the proper a-c voltage rating, (RMS) depends upon a number of factors, several of which are not easily obtained before you start actual construction of the power supply.

When you select a transformer remember that the D-C OUTPUT is always less than the A-C VOLTAGE RATING—RMS—of the transformer. It will be necessary for you to make allowance for all the additional voltage drops that tend to reduce the d-c voltage output. In general, these are the voltage drops that must be figured in—

DROP DUE TO THE LOAD
DROP DUE TO THE BLEEDER
DROP DUE TO THE FILTER SYSTEM USED
DROP ACROSS THE RECTIFIER TUBE

The amount you will allow for each of these drops depends upon the circuit being used. For example—the drop caused by a receiver operating under a light load will be small, but the drop caused by a transmitter will be large. These drops will be still further affected by the current-carrying capacity of the rectifier tube, and whether or not the transformer is operating near capacity.

To complicate things further, filter systems under light loads will have a smaller voltage drop than those operat-

ing under full or heavy load. A CHOKE input will produce a LARGER drop in voltage than a CONDENSER input when light loads are used. If the load is HEAVY, the situation is REVERSED.

And don't ignore the IR drop across the rectifier type. This is one of the largest drops, especially if the circuit uses a high-vacuum tube. Below are a few examples of these drops for tubes operating at 50 percent of their rated current-carrying values.

TYPE OF TUBE	VOLTAGE DROP
80	62 volts (per plate)
81	120 volts (half wave)
5Z3	61 volts
83V	22 volts
836	110 volts

If your rectifier is to use a MERCURY-VAPOR TUBE, the drop will be constant at approximately 15 volts for all values of current within the rated abilities of the tube. You'll hear more about this later.

SELECTING THE TRANSFORMER

As you can see, this all adds up to a complicated problem. All these factors must be taken into consideration. But without elaborate equipment for measurement and without a good working ability of advanced mathematics, you'll put it down as a hopeless case. Fortunately, several "rules of thumb" are used to guide the practical man in his selection.

RULE ONE—Choose a transformer that will produce MORE than the necessary a–c voltage output. Remember you can reduce the d-c voltage output to the desired level by TAPPING OFF on the bleeder resistor.

RULE TWO—If the transformer and rectifier are to operate at 50 percent of the rated current value, multiply the required d-c output voltage by $\frac{5}{3}$. The resulting figure will usually be a satisfactory transformer voltage. For example—if you wish to have a d-c output of 300 volts, choose a transformer that delivers a 500-volt a.c., RMS.

In summary—choose a transformer that has a much larger current-carrying ability and a higher output voltage than is necessary. You will then be sure that the transformer is capable of doing its job properly.

TRANSFORMER TERMINAL IDENTIFICATION

You will need to know how to identify the various windings of the power-supply transformer by the color of the insulation on the lead wires. The following table is used by most transformer manufacturers. Learn the table or know where to find it so you can refer to it when necessary.

COLOR CODE FOR POWER TRANSFORMERS

WINDING	COLOR
Primary	Black
Primary center tap	Black and yellow
High-voltage secondary	Red
Center tap. H-V secondary	Red and yellow
Rectifier filament leads	Yellow
Rectifier center tap	Yellow and blue
Filament winding No. 1	Green
Filament center tap No. 1	Green and yellow
Filament winding No. 2	Brown
Filament center tap No. 2	Brown and yellow
Filament winding No. 3	Slate
Filament center tap No. 3	Slate and yellow

Many times, especially with used transformers, you will find that the color on the insulation is gone. In this case, the LARGEST wires will be the RECTIFIER FILAMENT SUPPLY, and the SMALLEST wires will be the HIGH VOLTAGE side. Other filament leads will be of sizes in-between the size of the plate and rectifier filament supply windings.

You may also check the windings by using the LOW-RANGE ohmmeter scale. The wires with the HIGHEST resistance will be the HIGH-VOLTAGE SECONDARY, the next highest should be the PRIMARY. The LOWEST resistance belongs to the rectifier filament supply. These methods are not absolutely dependable and should be used only in an emergency.

SELECTING THE RECTIFIER TUBE

Two factors must be considered in selecting the rectifier tube. They are—CURRENT-CARRYING ABILITY and MAXIMUM SAFE INVERSE-PEAK VOLTAGE.

A rectifier tube should not be operated at an AVERAGE load level that is greater than 50 percent of its RATED VALUE. If your power supply is called upon to supply 200

Ma. choose a tube that is capable of delivering about 400 Ma. If the tube is to be subjected to large changes in its load, such as in a transmitter used in sending Morse code, it is well to make this safety margin greater than 50 percent.

SAFE INVERSE PEAK VOLTAGE

The safe inverse peak plate voltage is the greatest NEGATIVE potential that can be placed on the plates without causing particles of the plate to fly over to the cathode. When the plate moves to the cathode, your tube is shot, washed-out, sunk. Calculate what the transformer voltage should be. If you find that this calculated voltage is GREATER than the safe inverse peak voltage, choose another tube that has a safe inverse peak voltage.

For example—after taking into consideration all the voltage drops of the circuit, you find that the transformer must deliver a potential of 1,500 volts to each plate. You have considered using a type 80 tube. The characteristics of this tube reveals that it has a safe inverse peak voltage of only 1,400 volts. Obviously, this tube will not be satisfactory. Thus you will select another tube that is capable of standing that voltage. A 5T4 or a 5U4-G tube will do.

OTHER FACTORS IN SELECTING A RECTIFIER TUBE

There are other factors that enter into the choice of a rectifier tube—the known ability of a particular tube to withstand OVERLOAD, the amount of current necessary to properly HEAT the filament and other characteristics of its physical construction. Some of this information can be gained by reading descriptions of the various tubes, but most of the know-how will have to come from practical experience.

The rectifier tubes mentioned thus far have all been high-vacuum types. Another tube, known as the MERCURY VAPOR RECTIFIER, will be discussed in the next chapter.

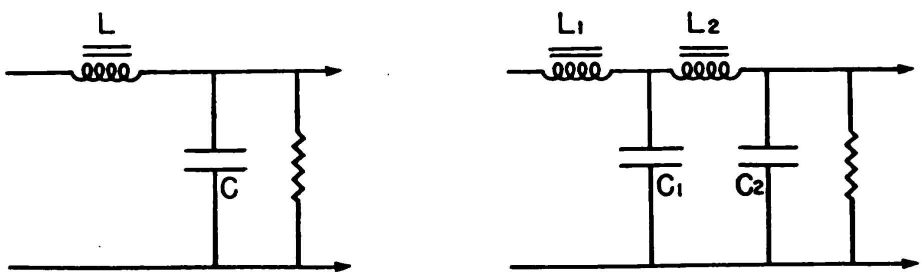
SELECTING THE PARTS FOR THE FILTER

The sizes of the filter condensers and chokes are largely responsible for determining the amount of ripple that is present in the output of the rectifier circuit. Every designer tries to reduce the ripple to the SMALLEST PRACTICAL value. The expression "smallest practical" is used

to express a compromise condition. Very large condensers and chokes could reduce the ripple to ALMOST ZERO, but the bulkiness of these condensers and chokes would make this impractical, since the added filtering gained would not be worth the additional expense and space required.

A radio designer will refer to the amount of ripple voltage present in terms of percentage. Ripple voltage is objectionable when it is greater than 5 percent of the average d-c output. A ripple voltage of 3 to 5 percent is considered good.

You will usually not have equipment to measure the amount of ripple and calculate the percentage, but you can judge whether the amount is objectionable by listen-



$$\% \text{ RIPPLE} = \frac{100}{LC} \qquad\qquad \% \text{ RIPPLE} = \frac{650}{L_1 L_2 (C_1 + C_2)}$$

122.—How to determine the approximate percent of ripple voltage for choke input filters.

ing to a receiver when it is NOT tuned to a station. If the a-c hum is audible, there is TOO MUCH ripple present and something must be done to correct it. There are other causes of a-c hum in a receiver than faulty filtering of the power supply, so if the hum is present after checking the condensers and chokes, you will have to look elsewhere for the difficulty. This type of servicing will be discussed fully in other chapters.

SIZES OF CONDENSERS AND CHOKES

With a condenser input, satisfactory filtering can be attained by using chokes with an inductance of 10 to 20 henries, and condensers of 8 to 10 mf. It is not an uncommon practice to use smaller chokes, 3 to 5 henries,

with condensers up to 40 mf. This arrangement works well in small receivers where the amount of current used is small.

With a choke input, satisfactory filtering can be achieved by using the same size condensers and chokes as are used with the condenser input. In addition to this, a simple mathematical relationship is available that may be used in calculating the percentage of ripple voltage.

Figure 122 shows the circuits and the equation for calculating the percent of ripple voltage that will be present in a single-section and a two-section choke input filter. Don't worry about the 100 and the 650 above the line in the equations. Someone did a lot of hard work to figure them out, and all that you need to do is use them.

VOLTAGE RATING OF FILTER CONDENSERS

You heard something about the filter condensers in the introductory chapter. Since it is an important topic, more information will be given here.

First of all, filter condensers are ELECTROLYTIC types. In other words these condensers have POLARITY. Remember what will happen if you make a mistake and REVERSE the condenser. Just to be sure that you do not make this mistake and insert the condenser backwards, here are some precautions—

Always connect the NEGATIVE terminal to the GROUND—the CENTER TAP of the HIGH-VOLTAGE SECONDARY. The POSITIVE terminal is always connected to the CATHODE or HIGH-VOLTAGE side of the BLEEDER RESISTOR. If the terminals are not marked + and —, the RED TERMINAL is always the POSITIVE connection of the condenser.

If the electrolytics are of the CAN TYPE the outer metal casing is usually the NEGATIVE terminal, and the center insulated contact is the POSITIVE connection. When you mount this condenser, be sure the metal of the can makes a good, clean contact with the metal chassis.

The second consideration is the VOLTAGE RATING of the condenser. Remember—the condenser must be able to stand ALL PEAK a-c surges. All transformer voltages are given in EFFECTIVE VALUES. Therefore, the PEAK A-C VOLTAGE will always be equal to the RATED A-C VOLTAGE $\times$ 1.41.

If a transformer is rated at 500 volts RMS, the peak

voltage will be $500 \times 1.41 = 705$ volts a.c. Therefore, the smallest maximum voltage rating permissible will have to be about 700 volts. Since the condenser may be subjected to even higher surge voltages, it is well to add another 100 volts, and pick a condenser that can stand a maximum peak voltage of 800 volts.

CHOOSING THE CHOKE

You'll need to take only one precaution in selecting a choke—it must be able to carry the required amount of current. Allow an ample margin of safety so that the choke will be able to take care of brief overloads. As an example—if the average current is 400 Ma, the choke should be able to carry 600 Ma without being damaged.

THE SWINGING CHOKE

The term "swinging choke" does not mean that the choke "floats through the air with the greatest of ease." Actually, the only thing that does swing is the INDUCTANCE of the choke. These chokes have a special type of core which permits the magnetic flux to change its density.

You'll use swinging chokes because a power supply operating under a HEAVY load requires LESS FILTERING than one operating with a light load. In order that the same percentage of filtering can be achieved under both conditions, it is necessary that the choke offer a HIGHER REACTANCE when a load is LIGHT.

Here is an example of the calculations you must make in selecting a swing choke that has the proper maximum and minimum inductance.

PROBLEM—A power supply is to furnish a maximum current of 500 Ma and a minimum current of 100 Ma. The d-c voltage is to be 1,500 volts. Find the maximum and minimum values of inductance for the choke.

SOLUTION—The inductance of the choke is found by the equation—

$$L = \frac{\text{D-C Resistance of the circuit}}{1{,}000}$$

The factor 1,000 is a constant that has been predetermined by mathematical computation.

The d-c resistance of the circuit is found by—

$$\text{D-C resistance} = \frac{\text{Applied voltage}}{\text{Current flowing}}$$

Therefore, for 500 Ma at 1,500 volts—

$$R = \frac{1{,}500}{0.500} = 3{,}000 \text{ ohms}$$

The inductance for this MAXIMUM LOAD must be—

$$L = \frac{3{,}000}{1{,}000} = 3 \text{ henries.}$$

The resistance for 100 Ma at 1,500 volts will be—

$$L = \frac{1{,}500}{0.100} = 15{,}000 \text{ ohms.}$$

The inductance for this MINIMUM LOAD will be—

$$L = \frac{15{,}000}{1{,}000} = 15 \text{ henries.}$$

Thus, the choke must have a SWING INDUCTANCE that lies between 3 and 15 henries in order for it to produce the correct filtering.

REGULATION IN A POWER SUPPLY

Several times, the word REGULATION, has been used in connection with power supplies and their filters. "Regulation" expresses the relationship of the d-c output voltage WITHOUT a load to the d-c output WITH a load. A power supply that has GOOD REGULATION is one that gives a SMALL DIFFERENCE in the d-c output voltage when under load and when without load.

The voltage in a power supply behaves very much like the pressure in a water pipe. At the instant the water tap is opened, the pressure is high, and the water will gush out. A few instants later, the rate of flow is reduced to a steady stream because of the REDUCTION OF THE PRESSURE in the pipe.

The same thing happens in a power supply. At the instant the switch in the d-c outlet is closed and current starts to flow, the voltage is HIGH. A split second later, you will find that the voltage has fallen to a level which

the power supply is able to maintain. This principle is illustrated in figure 123.

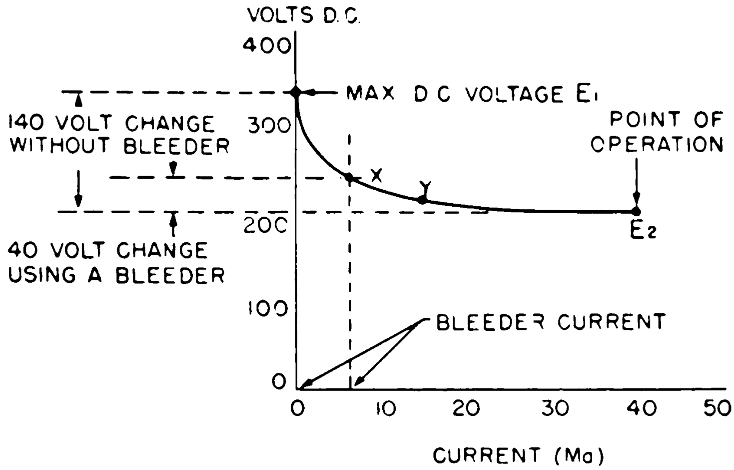


Figure 123.—Regulation of a power supply.

Notice in figure 123, that at NO LOAD (when no current is flowing) the potential is 350 volts. When the set is turned on, the current flowing through the circuits is 40 Ma. The d-c voltage at that load will be only a little more than 200 volts. This situation is not good, and if you sent Morse code with a transmitter having such a power supply the transmitter would "chirp like a bird."

The REGULATION for any power supply is given in percentages and is found by the following equation—

$$\text{Percent of Regulation} = \frac{(E_{\text{no load}} - E_{\text{load}})}{E_{\text{load}}} \times 100$$

For example—substituting the values from figure 123, you will have—

$$\text{Percent of Regulation} = \frac{(350 - 200)}{200} \times 100 = 75\%$$

The regulation of this power supply is POOR. The SMALLER the percentage, the BETTER the regulation.

IMPROVING THE REGULATION

The regulation can be improved greatly by placing a BLEEDER RESISTOR of the proper size across the power supply. Notice point *X* in figure 123. It is located at the intersection of the 240-volt and the 6-Ma lines. If the bleeder resistor is connected to carry these 6 Ma of cur-

rent, the fluctuation in the output voltage will be between 240 and 200 volts. In this case, the regulation will be—

$$\frac{(240 - 200)}{200} \times 100 = 20\%$$

This regulation is not excellent, but it is much better than the 75 percent regulation WITHOUT the bleeder. Further improvement could be made by making the bleeder carry even more current.

CALCULATING THE SIZE OF THE BLEEDER

Using the same problem of figure 123, you can easily calculate the resistance that the bleeder must have in order to carry the 6 Ma of current. The voltage across the bleeder with 6 Ma of current is 240 volts. Therefore the resistance of the bleeder must be—

$$\frac{240}{0.006} = 40{,}000 \text{ ohms.}$$

If you wish to have the bleeder carry 15 Ma of current, as at point *Y*, figure 123, the resistance of the bleeder must be—

$$\frac{220}{0.015} = 14{,}680 \text{ ohms, or approximately } 15{,}000\ \Omega$$

The POWER RATING for the 6-Ma current must be—

$$240 \times 0.006 = 1.5 \text{ watts, approx.}$$

If the bleeder is NOT also acting as a VOLTAGE DIVIDER, a 2-watt resistor will be large enough. But if it is also a voltage divider, you must solve the problem as it was worked out in chapter 4.

SOURCES OF TROUBLE IN POWER SUPPLIES

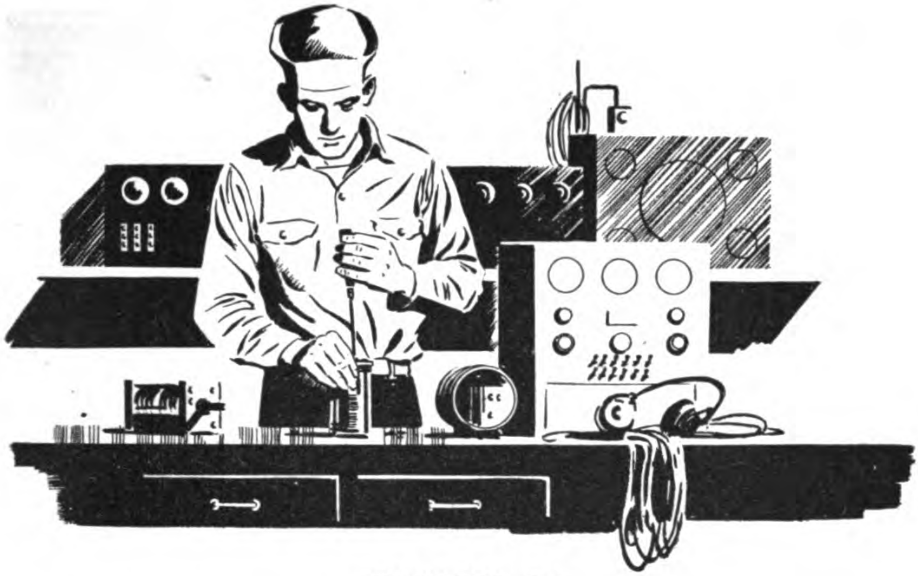
Power supplies can be working perfectly, and suddenly trouble will develop. If you turn off the line voltage immediately, the damage will usually be small, but if the set is left on, serious damage and an expensive repair job will result.

Like measles, smallpox, and mumps, the symptoms of power supply troubles are easily diagnosed by the experienced technician. The following table is a list of the most common failures and their symptoms.

FAILURES IN A POWER SUPPLY

DEFECT	SYMPTOM	CHECK	CURE
1. Open primary winding.	1. No a-c voltage in the secondary.	1. Disconnect primary and check with ohmmeter for open circuit.	1. Replace transformer.
2. One leg of H-V secondary is open.	2. Will act as half-wave rectifier. Lower d-c output. D-C hum of a lower pitch.	2. Check both legs with the ohmmeter.	2. Can continue to use in emergency, replace if possible.
3. Burned or shorted transformer.	3. Hot or smoking transformer. Usually no output voltage.	3. USE YOUR NOSE. Transformer will smell burned. Check from primary to secondary with ohmmeter for possible short.	3. Replace transformer.
4. Tube low on emission.	4. Low d-c output.	4. Check with tube tester. Check heater voltage.	4. Replace tube. If heater terminal is open, correct.
5. Tube filament burned out.	5. Tube will not light up.	5. Check filament with ohmmeter.	5. Replace tube.
6. Tube filament shorted to plate.	6. Plates may get red. Transformer will get hot.	6. Check filament to plate for short.	6. Replace tube.
7. Shorted external circuit.	7. Rectifier plates will turn red. Sparks may fly between cathode and plate. Output voltage is low.	7. Check filter and circuit for short.	7. Replace the shorted part and tube. Tube is gassy.
8. High-vacuum tube is gassy.	8. Tube will glow blue.	8. No further check necessary.	8. Replace tube.
9. Input condenser open.	9. Drop in output d-c voltage.	9. Check with a condenser tester.	9. Replace condenser.

DEFECT	SYMPTOM	CHECK	CURE
10. Shorted input filter condenser.	10. Tube usually burned out. Transformer hot. If not discovered soon, transformer will burn out also.	10. Check condenser for short. Check tube. Check transformer for possible short. Apply the "smell" test to the transformer.	10. Replace shorted or burned-out parts.
11. Shorted input choke.	11. Rise in output voltage.	11. Check choke for short, using LOW-OHM range on ohmmeter.	11. Replace choke.
12. Open bleeder.	12. Electrolytics will not discharge. Regulation will become poor.	12. Check for open bleeder circuit.	12. Replace bleeder.
13. Overloaded bleeder.	13. Bleeder will be very hot and may burn.	13. Observe how the bleeder warms up.	13. Replace with a bleeder of larger power rating or one with higher resistance.
14. Overloaded power supply.	14. Excessive heating of all parts of power supply, especially the transformer. Plates of tube may become red.	14. Check all parts of external circuit for possible shorts.	14. Correct all shorts. Replace any damaged parts. If necessary, build a larger power supply.
15. Open circuit at any point in power supply.	15. No output voltage.	15. Check all circuits with an ohmmeter.	15. Correct the open circuit.



CHAPTER 16

MORE POWER SUPPLIES

THREE-PHASE

The greatest number of power supplies you will use are of the types just studied. But, there are others in common use. Usually they are designed for special purposes. Fortunately, most special power supplies are combinations of the principle circuits that you already know. One of these, the three-phase power supply, is designed to be used with three-phase a.c. It has the advantage of being able to deliver a larger amount of power with less filtering.

The three-phase half-wave rectifier acts as THREE half-wave rectifiers connected in such a manner that each plate becomes POSITIVE once in every 360 degrees of phase rotation.

Notice in figure 125 that curve *A* starts to rise from zero at point *X*. After a 120 degree delay, curve *B* starts to rise, after another 120 degrees delay, curve *C* begins to rise. When a complete cycle of 360 degrees has passed, curve *A* is back at the starting point ready to begin the cycle again. Thus, current will flow first to plate *A*. One hundred and twenty degrees later it will start flowing to plate *B*. And 120 degrees after that, current will flow to plate *C*. At the end of a complete cycle, plate *A* will again be positive, and the whole process is started over again.

The pulsating d.c. produced by the three-phase rectifier is illustrated in line *A*, figure 126. Notice how each curve is overlapped by the following wave. Thus you see in line *B* that the d-c voltage is never permitted to fall to

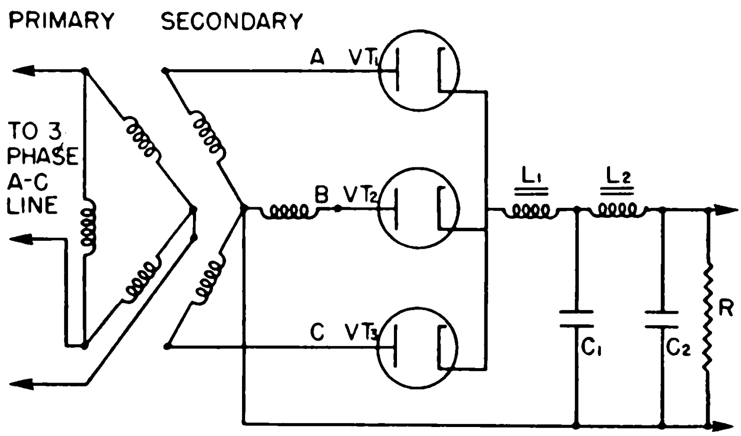


Figure 124.—Schematic diagram for a three-phase rectifier.

zero. Mathematically, with a three-phase rectifier, the pulsating d-c voltage NEVER falls to a value LESS THAN 50 percent of the peak d-c voltage.

Now about the voltage waves in lines *D* and *E*? With

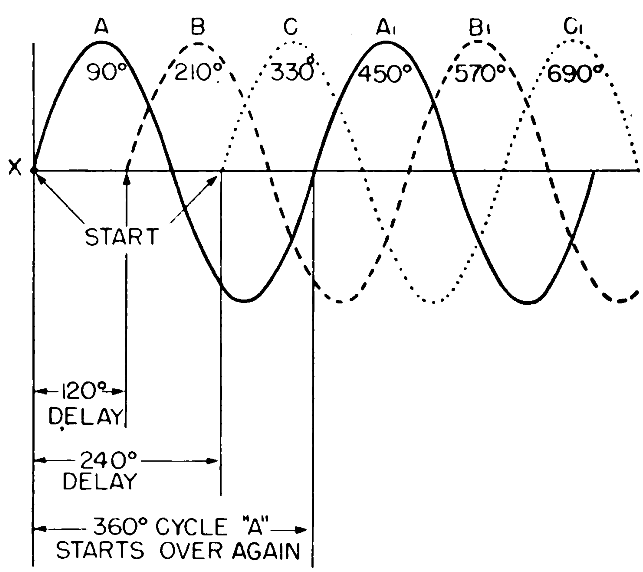


Figure 125.—Three-phase a.c.

the FULL-WAVE rectifier, the d-c voltage falls to zero once in every 180 degrees of rotation. But with the HALF-WAVE rectifier, the voltage falls to zero EVERY OTHER 180 degrees, and remains there for the next 180 degrees.

FILTERING RECTIFIED THREE-PHASE A.C.

One of the advantages of using three-phase a.c. for rectification is the ease with which the pulsations can be

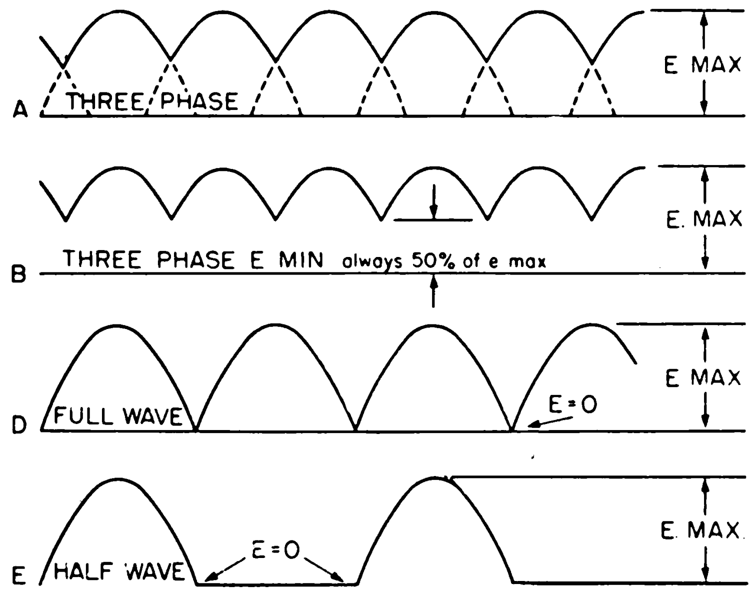


Figure 126.—Pulsating d.c. produced by three-phase and half-wave rectifier.

filtered. The fact that the pulsating d.c. never falls to a level less than 50 percent of the peak value means that the valleys will require less filling in order to bring the output voltage to a constant level.

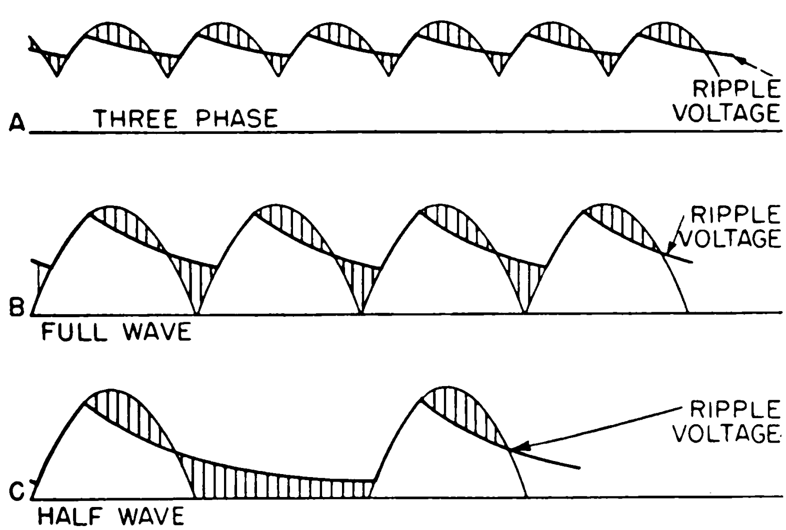


Figure 127.—Action of filters on three-phase, full-wave, and half-wave rectification.

Compare the three lines *A*, *B*, and *C* of figure 127. The ripple of the three-phase rectifier is the LEAST pro-

nounced, and the half-wave ripple is the MOST pronounced. Hence, if you desire the same percentage of ripple voltage with the half-wave or full-wave rectifiers as you can get from the three-phase rectifier, you must use larger filter condensers and chokes.

The three-phase rectifier described here uses HALF-WAVE rectification. Therefore, the ripple frequency will be equal to 3 $\times$ frequency of each phase.

For example—the ripple frequency for a 3-phase half-wave frequency is $3 \times 60 = 180$.

The pulsations are closer together, and the minimum d-c voltage never falls to a value less than 50 percent of the peak. Hence the average value of the filtered d-c voltage is greater than it is for either the half-wave or the full-wave single-wave rectifier. You can observe that by drawing a line half-way between the top and bottom points of the curves in figure 126.

BRIDGE RECTIFIERS

The BRIDGE RECTIFIER has poor regulation at low voltages, and is used only when high d-c voltages are re-

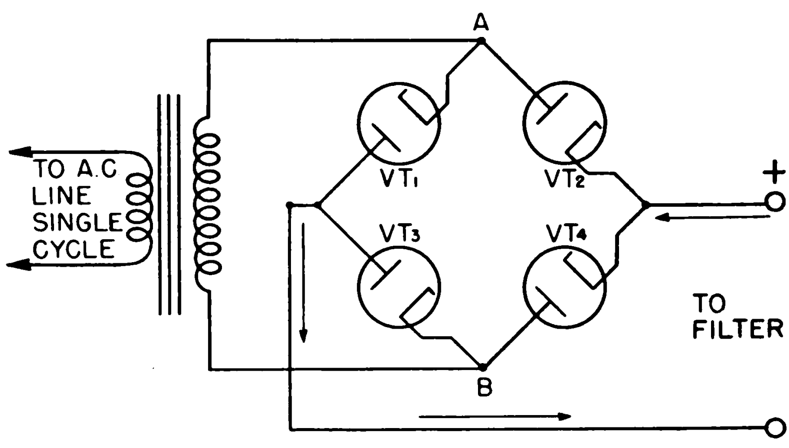


Figure 128.—Single-phase, full-wave bridge rectifier circuit.

quired. Notice in figure 128 that the diode tubes are connected to form a diamond-shaped circuit. Tubes VT_1 and VT_3 are connected in series between the terminals of the transformer at points A and B. In the same manner, VT_2 and VT_4 are in series between points A and B. The two series circuits in turn form a parallel circuit, so, between points A and B, the four tubes form a SERIES PARALLEL circuit.

The bridge rectifier permits a higher voltage output.

As an example, suppose that 3,000 volts a.c. is impressed by the transformer across the bridge between terminals A and B. HALF of this voltage will appear across VT_1 and VT_2. The OTHER HALF will appear across the other two tubes. Thus, the voltage across any one tube is not greater than 1,500 volts.

Here is where the peak inverse voltage comes into play. If a single tube were used, it would have to be able to stand the full 3,000 volts. Such a tube is difficult and expensive to make. By using a bridge, tubes with a much lower inverse peak voltage can be used since only half the applied a.c. appears across each tube.

The bridge rectifier permits the use of a simpler transformer. The elimination of the center tap reduces its cost and size, since it is possible to use the full secondary voltage and still obtain full-wave rectification.

HOW THE BRIDGE RECTIFIER WORKS

To understand how the bridge rectifier works, remember that current will flow through the tube whenever the PLATE is MORE POSITIVE than the CATHODE. If a positive potential is applied to the plate, or a negative potential is applied to the cathode, current will flow.

Figure 129 shows how the bridge rectifier works. In the top schematic, the transformer places a POSITIVE potential on the PLATE of VT_2 and a NEGATIVE potential on the CATHODE of VT_3. In each case, the plate is more positive than the cathode, so current will flow. During the same half-alternation, the cathode of VT_1 and the plate of VT_4 are both negative. Therefore no current will flow through these two tubes and they can be considered OUT OF THE CIRCUIT.

To trace the flow of current through the circuit, start at the cathode of VT_2 and follow the arrow to the plate, then through the transformer, and into VT_3. From this tube VT_3 the current flows out through the load and back to the starting point.

During the next half-alternation, shown in the bottom drawing of figure 129, all potentials in the rectifier circuit are reversed. Tubes VT_1 and VT_4 are now conducting current, and the other tubes are idle. Notice that the flow of d.c. through the load is still in the SAME DIRECTION as it was before.

DRY RECTIFIERS

The DRY RECTIFIER found considerable use in the early days of radio but soon passed into secondary importance. Recently this type of rectifier has found new uses and is again becoming important.

The construction of this rectifier is simple. Instead of using vacuum tubes, it uses plates of COPPER and copper oxide or SELENIUM and its oxides. These plates are placed in a PILE with a copper plate next to a copper oxide plate, and so on. Figure 130 is an assembly of a SELENIUM RECTIFIER.

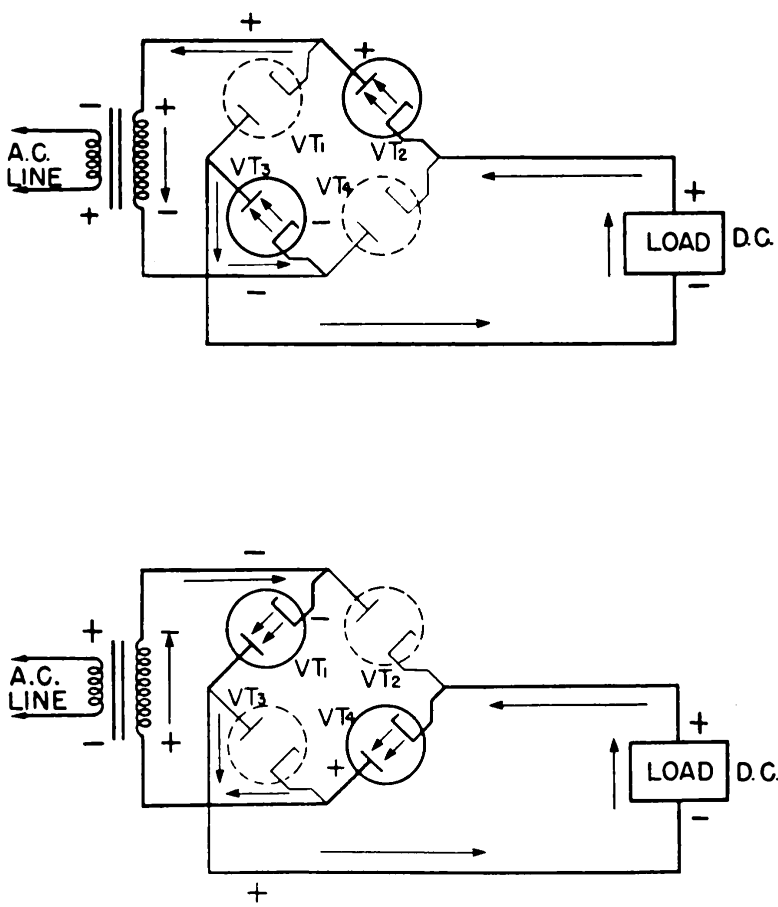


Figure 129.—Operation of a bridge rectifier.

This arrangement of metals and their oxide plates forms a circuit that offers a high resistance to the flow of current in one direction, and a low resistance in the other. That's how the a.c. is rectified to d.c.

The circuit in figure 131 is quite similar to the bridge rectifier you just finished reading about. Four rectifier piles are connected to form a bridge. They are arranged

so that the piles will permit current to flow in only one direction.

The first step in understanding how this rectifier works is to keep remembering that electrons will flow TOWARD the POSITIVE potential.

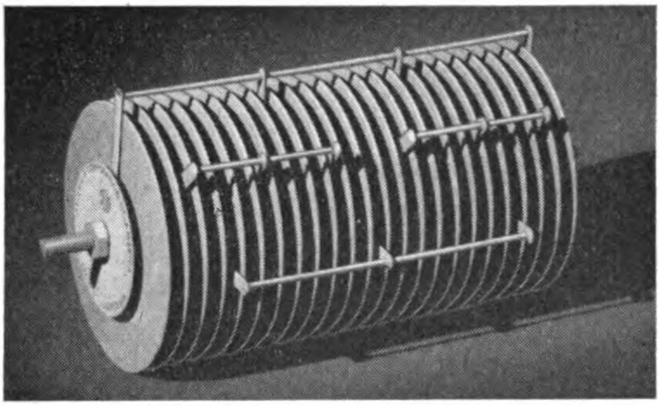


Figure 130.—Copper, copper-oxide rectifier pile.

The arrow heads in the rectifier schematic point in the DIRECTION THE CURRENT FLOWS. You can remember this if you say to yourself that current will NOT flow AGAINST a sharp point. In the top drawing of figure 132, the UPPER leg of the transformer is positive. Current will flow through R_2, the transformer, R_3, and out through the load. On this half-cycle, current cannot flow through R_1 or R_4 to the positive leg of the transformer because it would have to move AGAINST the SHARP POINTS of the rectifier piles.

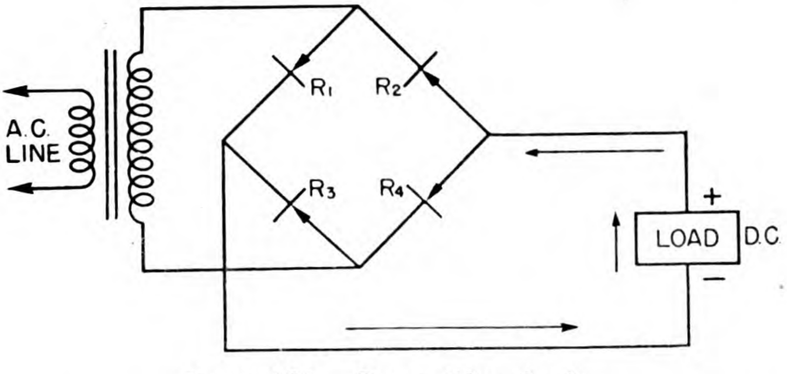


Figure 131.—Dry rectifier circuit.

In the second drawing of figure 132, the a-c voltages have reversed themselves, and now the current is flowing through the other two rectifier piles. If you ever get stuck as to the direction the current flows, just FOLLOW THE ARROWS—they point the way.

USING RECTIFIER TUBES IN PARALLEL

Many times it is necessary to have a power supply deliver more current than a single rectifier tube is capable of passing. In this case, a second diode is connected in PARALLEL with the first. This parallel connection is accomplished by connecting the two plates together. Since the cathodes are connected to a common heater source, they too will be in parallel.

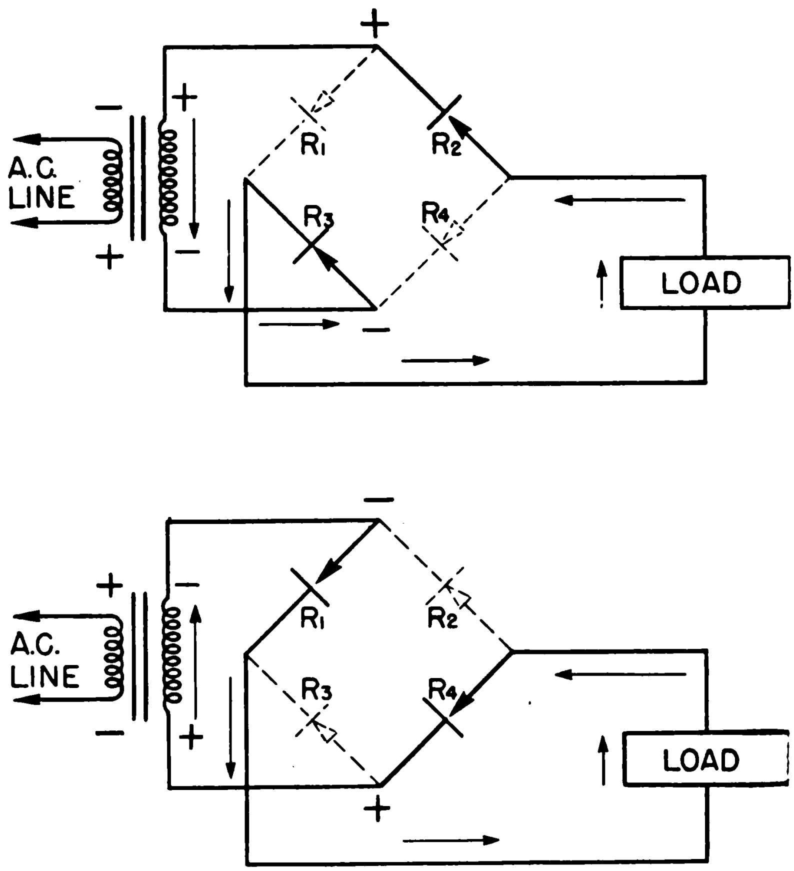


Figure 132.—Operation of a dry rectifier.

What you are actually doing by this parallel connection is making the plates of the diode TWICE AS LARGE. Therefore it sholud be able to pass twice as much current as a single diode.

Figure 133 shows how to connect tubes in parallel to make a full-wave rectifier. Tubes VT_1 & VT_2 and VT_3 & VT_4 are in parallel and act as a single large duo-diode.

The new CIRCUIT operates exactly as if you had a simple full-wave rectifier using a DUO-DIODE.

SOMETHING FOR NOTHING—ALMOST!

The VOLTAGE DOUBLER is one of the most interesting power-supply circuits. It is used with light loads, such as small receivers, and is able to deliver a d-c voltage that is more than TWICE the a-c input voltage.

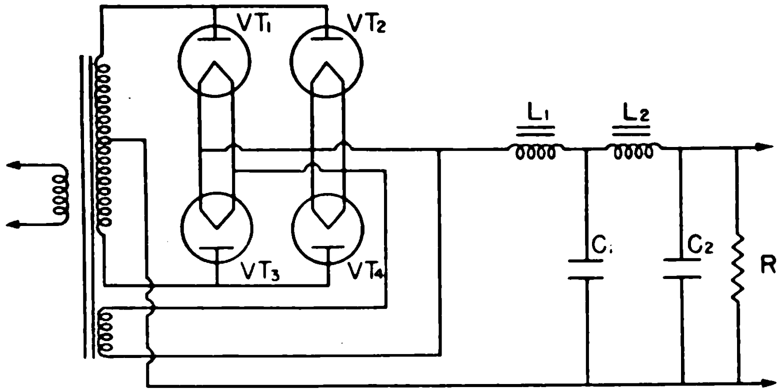


Figure 133.—Full-wave rectifier using parallel diodes.

The circuit in figure 134, uses two diodes and two condensers. The LOAD is diagrammed as a RESISTANCE. Observe that condensers C_1 and C_2 are connected in SERIES,

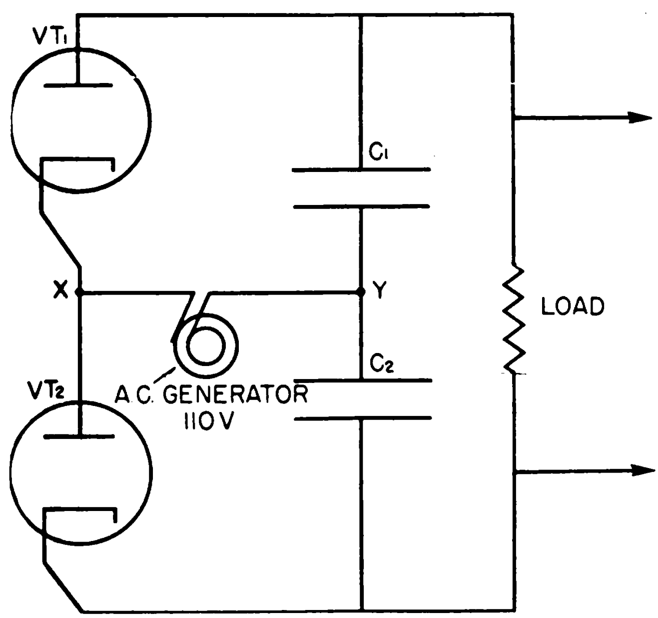


Figure 134.—Voltage doubler circuit.

and the CATHODE of VT_1 is connected to the PLATE of VT_2. The a-c input or generator is connected to point X between the tubes, and to point Y, between the condensers. While in this circuit, two separate tubes are indicated, usually one tube with two cathodes and two plates are used.

HOW IT DOUBLES THE VOLTAGE

The voltage doubler is actually a combination of three separate circuits. The GENERATOR, tube VT_1 and condenser C_1 form one of the CHARGING circuits. The generator, with VT_2 and C_2 form the other charging circuit. The third or DISCHARGING circuit is made up of C_1, C_2 and the LOAD RESISTANCE. Although the circuits work together to DOUBLE the voltage, they may be considered as independent of each other in their actions.

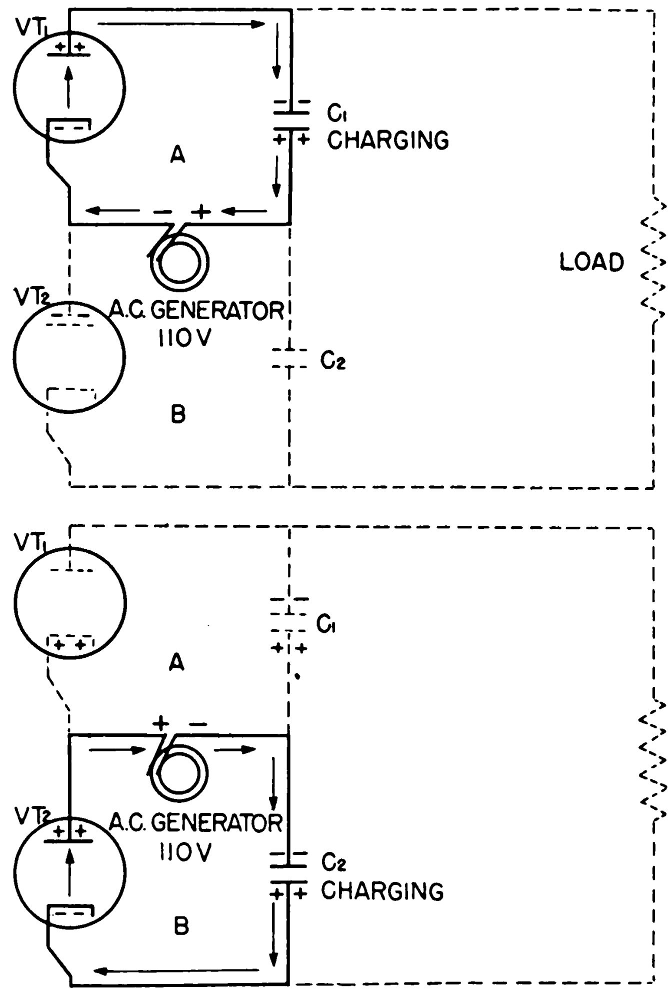


Figure 135.—How the condensers charge in a voltage doubler.

The first step in analyzing functions of a voltage doubler is to see how each condenser charges. First, consider the upper drawing of figure 135. Notice that the generator is on the HALF ALTERNATION which will make the CATHODE of VT_1 and the PLATE of VT_2 NEGATIVE. What will happen in this situation. Electrons will flow

from the cathode of VT_1 to the plate of VT_1, but NOT to the plate of VT_2.

Therefore on this half cycle, the generator will pump electrons OUT of the BOTTOM PLATE of the condenser C_1, through VT_1, and onto the TOP PLATE of that same condenser C_1. Since the bottom plate has lost electrons, it will become POSITIVE, and the top plate will become NEGATIVE.

If the load on this rectifier circuit is light, the condenser C_1 will charge to NEARLY PEAK VALUE of the a.c. Hence, if 110 volts a.c., RMS is delivered by the generator, the PEAK volume of the a.c. potential will be—

$$110 \times 1.41 = 155.1 \text{ volts.}$$

Thus condenser C_1 is capable of being charged to about 155 volts.

On the next half alternation, the generator has reversed its polarity. The cathode of VT_1 and the plate of VT_2 are positive. Tube VT_1 will not conduct, but current will flow from cathode to plate in VT_2.

During this half alternation, the generator will draw electrons OFF the LOWER PLATE of condenser C_2 and will deposit them on the TOP plate, charging condenser C_2 to near peak value of the a-c input voltage.

You can say that condenser C_1 charges on the NEGATIVE half-cycle and C_2 on the POSITIVE half-cycle. Each condenser charges INDEPENDENTLY of the other, and each is capable of developing a potential equal to the peak a-c voltage.

It is in the DISCHARGING circuit that the actual DOUBLING of voltage takes place. Notice that condensers C_1 and C_2 are connected in series. Do you remember about VOLTAGES IN SERIES? If batteries are connected in series—for example, four cells of 1½ volts each—the combined voltage of the four individual cells is 6 volts. And, the condensers act exactly like INDIVIDUAL CELLS connected in SERIES. Therefore, if the potential developed across each condenser is 155 volts, the COMBINED POTENTIAL of the two condensers in series would be—

$$155 + 155 = 310 \text{ volts.}$$

Since the condensers have a definite polarity that is never reversed, the output is d.c.

The two condensers C_1 and C_2 discharge IN SERIES

through the resistance of the load, and the average d-c output voltage is always the SUM of the average voltages developed across the individual condensers.

In practice, you never will be able to get 310 volts d.c. from a 110-volt a-c RMS input. But it will not be uncommon to get d-c potentials of almost 275 volts. The size of the d-c potential depends upon three factors—the AMOUNT OF CURRENT being drawn by the load, the SIZE OF THE CONDENSER, and the CURRENT-CARRYING CAPACITY of the tubes. If the current drawn by the load is not greater than 10 percent of the capacity of the tube, and the condensers are of 8 to 10 mf. or greater, it will be possible to get d-c potentials GREATER than 275 volts.

Be careful of this circuit. It is temperamental but, if

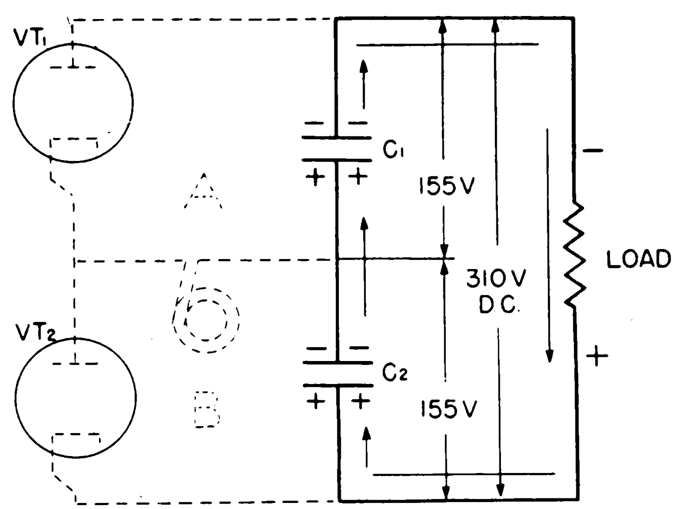


Figure 136.—Discharging circuit of a voltage doubler.

properly used with condensers of the correct voltage rating, you will find it extremely useful. This circuit is used for jobs other than power supplies. Don't be surprised if you see it in some control and amplifier circuits. Technicians have also found ways of using the voltage-doubler principle to triple, quadruple, and even multiply the a-c voltage input by five or six.

MERCURY VAPOR RECTIFIER

The common type of MERCURY VAPOR RECTIFIER tube is much like the ordinary diode, except that the cathode is coated with a small amount of MERCURIC OXIDE. When the cathode is heated, a small amount of mercury is vaporized and forms a cloud around the cathode. When the plate of

the tube is made positive, the mercury vapor will IONIZE —break into particles that are charged positive and negative. The NEGATIVE charges—the ELECTRONS—are drawn to the POSITIVE PLATE. The POSITIVE IONS are lonesome and are out looking for company, so they move to the negative plate and attach themselves to the FREE ELECTRONS on the plate. Other positive ions attach themselves to electrons in the space charge.

When the positive ions PICK UP the electrons in the space charge, they accomplish two acts. The space charge is REMOVED, and the positive ions are no longer ions, but once more are ATOMS. The atom starts to cruise around between the cathode and plate. By so doing, more of its electrons are knocked off. Once more it will form positive ions, and go through the act all over again.

Hence, as fast as the space charge is formed, the positive ions remove it (NEUTRALIZE IT). The neutralization of this space charge acts just the same as getting the interested bystanders out of your way when you are trying to work. If there is much interference by other people, it will be difficult for you to move about your work. Within the vacuum tube, all the EXTRA electrons in the space charge act as bystanders getting in the way of those electrons that are trying to get to the plate. Now if the POSITIVE IONS OF MERCURY are able to take the electrons for a one-way ride, the other electrons will be able to get from the cathode to the plate with greater ease.

Thus, by coating the cathode of a diode with a small amount of mercuric oxide, you increase the AMOUNT OF ELECTRONS that are able to move from the cathode to the plate. This added amount of current makes the mercury vapor tube most useful in power supplies where large quantities of current are required.

PRECAUTIONS

The mercury-vapor rectifier is delicate and can withstand very little abuse, but if you use it carefully and follow a few rules, it will be a steady and reliable workhorse. Here are the important precautions—

FIRST—Never turn on the HIGH VOLTAGE until the CATHODE is thoroughly warmed. If you do, the positive ions will fly back and bombard the cathode.

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These ions will travel at such a high velocity that they will cause the cathode to disintegrate.

SECOND—Never OVERLOAD this tube. An overload, even for an instant, will cause cathode disintegration.

THIRD—Always use this rectifier tube with a CHOKE INPUT FILTER.

FOURTH—Never attempt to use this tube when the air surrounding it is very cold. If it is necessary to use the tube in cold climates, an auxiliary electric heating element must be provided.

ADVANTAGES

There are two outstanding advantages to using the mercury-vapor rectifier. The first is its ability to carry LARGE QUANTITIES OF CURRENT. Second, within the rated current values of the tube, the POTENTIAL DROP across the tube IS ALWAYS 15 volts.

POWER SOURCES FOR RECEIVERS AND TRANSMITTERS

Only a small quantity of power, less than 200 watts, is needed to operate a RECEIVER. You can use the average 110/120-volt a-c line as a power supply for a receiver. This a-c supply is used as a source of a.c. and d.c. to operate the set.

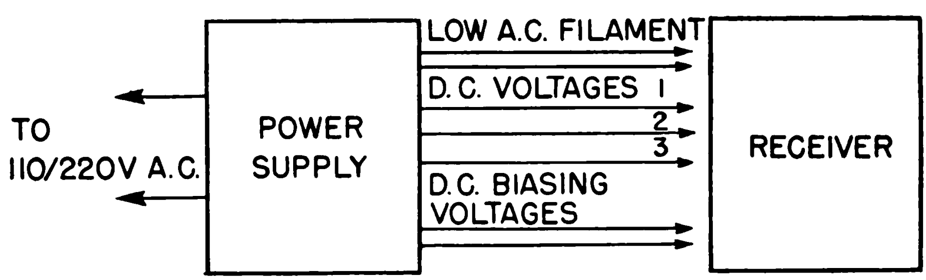


Figure 137.—Source of power to operate a receiver.

A typical receiver power supply is shown in figure 137. The circuit is usually a full-wave rectifier with filters of the types you have already studied.

Transmitters require a more elaborate power source than receivers, since transmitters need MORE POWER at HIGHER VOLTAGES than a conventional rectifier-power supply can furnish.

Most transmitters have a motor-generator set to supply the power. There is considerable variation in these units,

depending upon the power requirements of the transmitter and the available line voltage.

Figure 138 is a block diagram for a two-generator set. The BIASING GENERATOR supplies a NEGATIVE d-c potential to the grids of the tubes. The other generator delivers an a-c voltage and TWO d-c voltages.

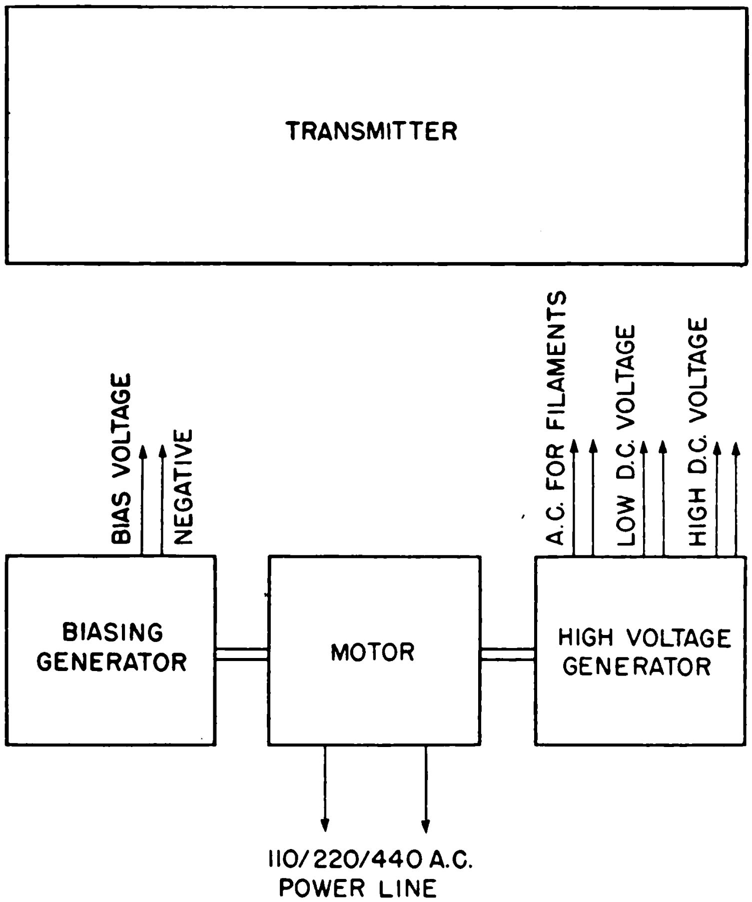
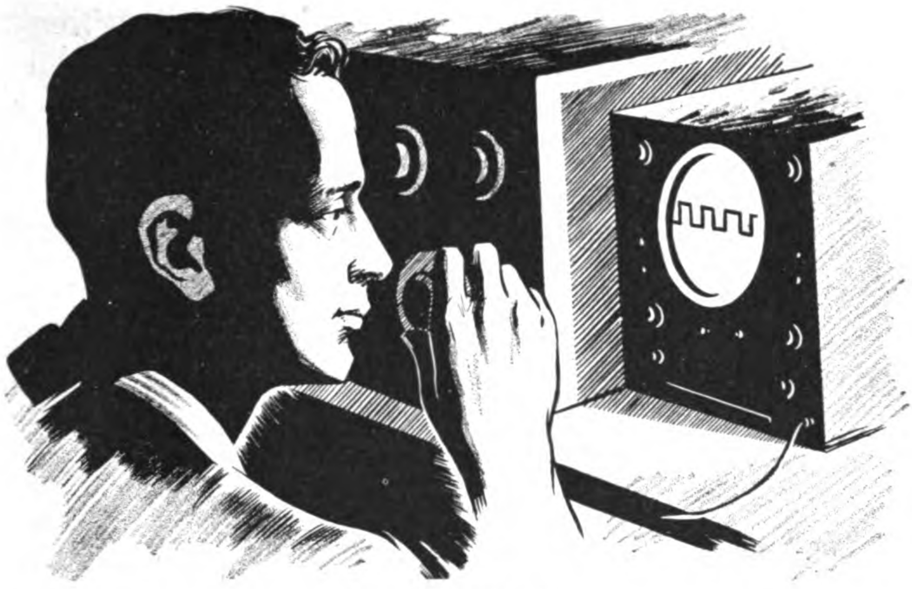


Figure 138.—Diagram of motor-generator set for a transmitter.

This arrangement will vary from installation to installation. Some motor-generator sets will deliver a high d.c., and others will generate two or more a-c voltages.

All these variations make it necessary that you learn the power system for each transmitter you work with. Two transmitters with the same serial number but of different modifications may have entirely different motor-generator sets.



CHAPTER 17

OSCILLOSCOPES

WHAT GIVES INSIDE THE CIRCUIT?

Remember the time Willie Jones fell from his bicycle and broke an arm? They rushed him to a hospital and took an x-ray. Looking at the plate, the doc rubbed his chin and said:

"Ah yes. Little Willie is suffering from a simple fracture of the distal half of the right humerous, fragments *in situ,* necrosis absent."

The OSCILLOSCOPE is the radio technician's x-ray machine. Hook one up, take a look at a cathode ray tube screen, and you can make a diagnosis like this—

"Ah yes. This TBK is suffering from a simple misalinement of the buffer stage or the superhet has spurious oscillations in the intermediate frequency stage and is suffering from gas in the triode-pentode converter."

See what an oscilloscope can do for you?

CATHODE-RAY TUBE

The cathode ray tube is the heart of the oscilloscope. Fundamentally, this tube is a large vacuum tube with the shape of a glass funnel—long, cylindrical, and flared at one end. The small end fits into the socket and is equipped with several contacts for the electrical controls. The

large end of the tube serves as the SCREEN. When the cathode ray tube is installed in an oscilloscope, you see only the screen end of the tube. The barrel and socket base are hidden inside the metal case of the 'scope.

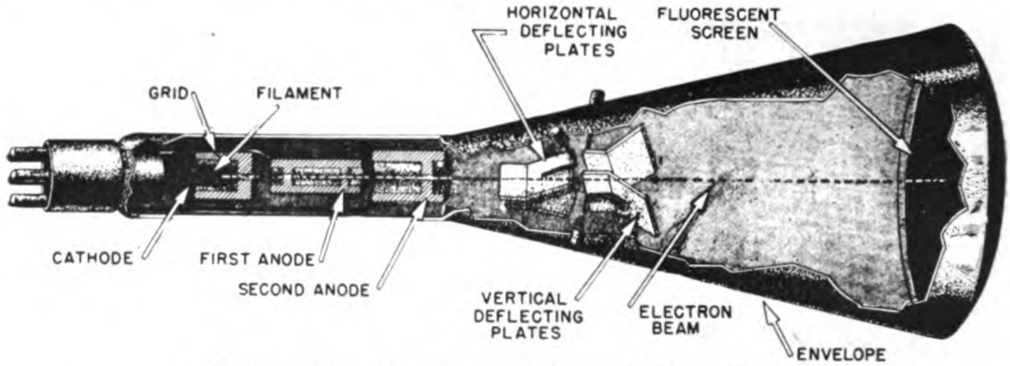


Figure 139.—Cross section of a cathode ray tube.

Slice a cathode ray tube in half lengthwise, and you'll have the diagram of figure 139. The FLUORESCENT SCREEN is painted on the inside of the enlarged end of the tube. All air is pumped out of the tube to create a HIGH VACUUM.

At the left-hand end of the tube, you have the ELECTRON GUN—an assembly of five parts, the cathode, filament, grid, first anode, and second anode.

Directly to the right of the electron gun are two sets of DEFLECTION PLATES. One pair is mounted in a HORIZONTAL position, the other in a VERTICAL position.

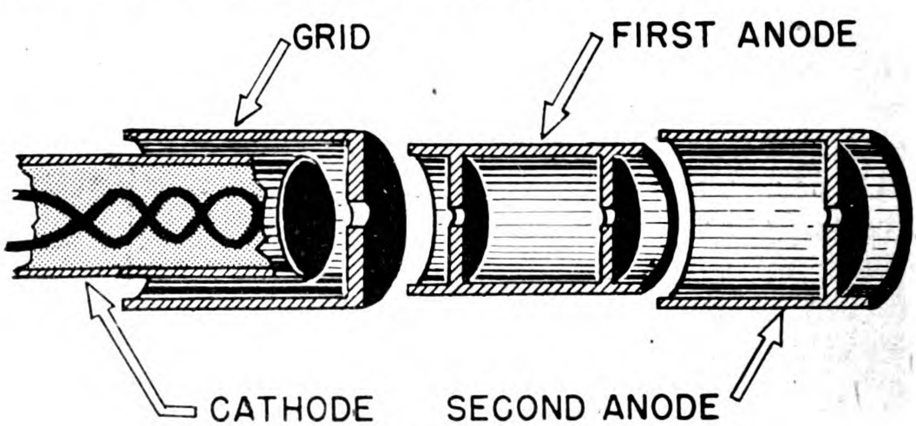


Figure 140.—Parts of an electron gun.

These parts are the only elements you'll find in the ELECTROSTATIC cathode ray tube. Later on you will hear about another type of CRT—the ELECTROMAGNETIC cathode ray tube.

THE ELECTRON GUN

The five parts of the electron gun—cathode, filament, grid, first anode, and second anode—act together to shoot a stream of electrons forward so they will hit the FLUORESCENT SCREEN of the cathode ray tube. Its gun-like tendency to SHOOT a stream of electrons gives this unit its name—the electron gun.

Figure 140 shows the arrangement of the parts of an electron gun in cross-section.

FILAMENT AND CATHODE

The filament and the cathode form a single unit. In figure 140, the cathode is a small metal container. One end of the container is open to permit the entry of the filament. The other end of the cathode is cup-shaped. The cup is filled with either barium oxide or thorium oxide. The filament is kept from touching the sides of the cathode by a plaster-like insulating material. The barium oxide or thorium oxide increases the number of electrons that will be given off by the cathode.

When the cathode is heated by the filament, ELECTRONS boil out of the barium oxide or thorium oxide and form a cloud—or space charge around the cathode.

THE GRID

The GRID resembles a tin can slipped over the end of the cathode. The hole punched in one end of the grid is a passageway through which electrons flow forward toward the FIRST ANODE.

The grid regulates the number of electrons that strike the fluorescent screen. This regulation is done by making the grid NEGATIVE with respect to the cathode. A very negative grid will stop the electron flow completely, but a LESS NEGATIVE grid will permit some electrons to pass through the grid opening. Thus, by VARYING the amount of NEGATIVE POTENTIAL on the grid, the INTENSITY or BRILLIANCE of the image on the fluorescent screen is controlled.

FIRST AND SECOND ANODES

The FIRST ANODE is a small can with a hole punched in the center of each end. The SECOND ANODE is a larger can

with one end cut away and a hole punched in the center of the other end.

The anodes FOCUS the stream of electrons into a sharp, fast-moving beam. When the electrons start out from the cathode, they are slow-moving and not too sure where they are going. The two anodes work as a unit to focus this cloud of sluggish electrons into a sharp, fast-moving BEAM, in much the same way as a lens focuses the beam

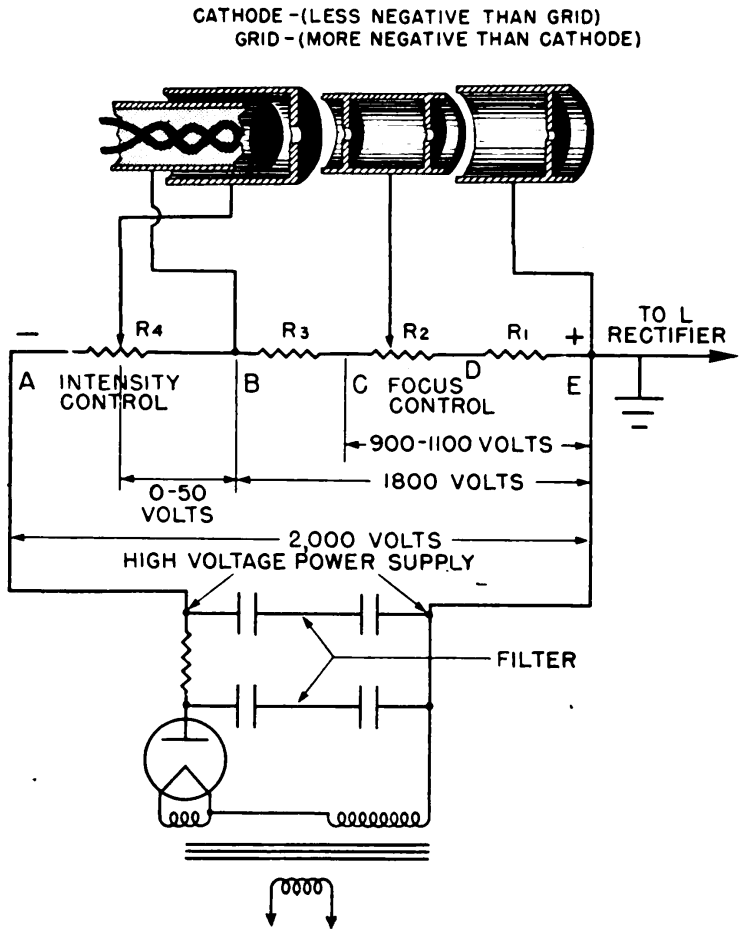


Figure 141.—Potentials to an electron gun.

of a flashlight. By the time the electrons leave the second anode, they are traveling toward the fluorescent screen at a speed of SEVERAL THOUSAND MILES A SECOND.

ELECTRON GUN POTENTIALS

Except for the second anode, whose potential is ground or zero, all the elements of the electron gun are at NEGATIVE potentials.

In figure 141 resistors R_1, R_2, R_3, and R_4 form a BLEEDER for a high-voltage power supply. Notice that the POSITIVE end of the bleeder is GROUNDED. This brings you to the subject of RELATIVE POTENTIALS again, and to the question of what you do to ALL OTHER POTENTIALS along the bleeder, when you ground the POSITIVE terminal of a bleeder.

Suppose you build a house below ground with the roof level with the surface of the earth. You certainly have a house, even though all deck levels are below the ground level. Likewise, in the case of this bleeder, you certainly have potentials, but since all are BELOW the GROUND level, you call them NEGATIVE potentials.

Now to test yourself on relative potentials. Reading from right to left in figure 141, the HIGHEST NEGATIVE potential is at point A. Reading from left to right, the HIGHEST POSITIVE potential is at point E. Thus point E is a higher positive than D, point D is higher positive than C, C higher than B, and B is higher than A.

You remember from the chapter on vacuum tubes that electrons always move toward the highest positive potentials. Electrons are given off by the CATHODE, which is connected to point B. Since the first anode is connected to a point of higher positive potential, electrons will move FROM the CATHODE TOWARD the FIRST ANODE.

The second anode is connected to a point of still higher POSITIVE POTENTIAL than the first anode. The difference in potential between the two anodes creates an ELECTROSTATIC FIELD whose direction is FROM the FIRST ANODE TOWARD the SECOND ANODE.

Electrons arriving at the first anode from the cathode are caught in this electrostatic field and whipped forward through the openings in the anodes at an ever increasing rate, like chips in a swift river. By the time the electrons reach the opening in the second anode, they are traveling fast enough to be thrown the length of the tube and end up striking against the fluorescent screen.

The GREATER the difference in potential between the anodes, the STRONGER the electrostatic field. The stronger the field, the FASTER is the movement of electrons toward the fluorescent screen. You INCREASE the strength of the field by moving the FOCUS CONTROL of R_2 toward point C. This actually makes the FIRST ANODE MORE NEGATIVE, but

has the same effect as making the SECOND ANODE MORE POSITIVE. Increasing the difference in potential between the anodes squeezes the electrons into a narrower and sharper beam.

If the focus control R_2 is moved toward point D, the difference in potential between the anode is REDUCED, the STRENGTH of the electrostatic field is reduced, and the beam striking the fluorescent screen will be thick and fuzzy.

HOW THE GRID WORKS

Look at figure 141 again. The GRID is connected to a point which is MORE NEGATIVE than the CATHODE. This means that the electrons leaving the cathode must pass this negative grid before they can get to the first anode.

If the grid is SLIGHTLY NEGATIVE, only a few electrons will be repelled back toward the cathode—most of the electrons will get through. If the grid is made more and more negative by moving the INTENSITY CONTROL R_4 toward point A, fewer and fewer electrons will be able to get through the grid opening. When the grid is made MAXIMUM NEGATIVE, NONE of the electrons will be able to get through.

Making the grid more negative reduces the intensity of the image on the fluorescent screen. You can make the grid negative enough so that NO image is visible. Normally, you make the grid potential just negative enough to hold back PART of the electron stream. If you want a brighter spot, reduce the negative potential by turning up the INTENSITY CONTROL. Never make the spot any brighter than is necessary, or you will damage the screen.

FLUORESCENT SCREEN

The FLUORESCENT SCREEN is made by painting a special chemical—willemite—on the INSIDE of the large end of the cathode ray tube. When the rapidly-moving electrons strike against this chemical, the willemite fluoresces or GIVES OFF LIGHT. The light given off is usually green, but you will often see a fluorescent screen that is designed to give off blue or white light.

Screens used with oscilloscopes are selected according to their PERSISTENCY—the length of time the screen will continue to glow after the beam of electrons has moved

to another point. Most oscilloscopes use a screen of low persistency so that the image disappears soon after the electron beam has moved on.

The Navy has several types of tactical equipment that are fitted with HIGH-PERSISTANCE screens. The image lasts until the electron beam moves around and reproduces it again.

THE DEFLECTING PLATES

Ever watch an artist paint a picture?

In many ways the fluorescent screen and the DEFLECTING MECHANISM will remind you of an artist at work. The ELECTRON BEAM is the paint brush and the deflecting mechanism is the artist's hand moving the electron beam across the fluorescent screen. By well-timed electrical PULSES, the DEFLECTION PLATES draw the image on the fluorescent screen.

To produce the movement of the electron beam over the entire screen surface. TWO PAIRS of deflection plates are used. In figure 139, these plates are located to the right of the second anode in such a position that the electron beam passes through the square opening formed by the four plates.

The plates are named according to the DIRECTION in which they CAUSE THE BEAM TO MOVE. The HORIZONTAL deflection plates can move the beam ACROSS the screen in a horizontal direction, while the VERTICAL deflection plates cause the spot to move UP or DOWN on the screen in a vertical direction.

HOW THEY MOVE THE BEAM

Here's your old friend, the law of charges—LIKE CHARGES REPEL and UNLIKE CHARGES ATTRACT. In figure 142, you are looking into the end of the deflection mechanism, with the electron beam hitting you right between the eyes after it has passed through the square formed by the four deflection plates.

Put a small POSITIVE charge on the RIGHT deflection plate. What will happen to the beam of electrons? The beam will bend toward the positive plate because the electrons in the beam are negative. If you place a positive charge on the TOP plate, the beam will move UP. Put positive charges on BOTH the right-hand plate and the top

plate, and the beam is bent toward the upper right-hand corner.

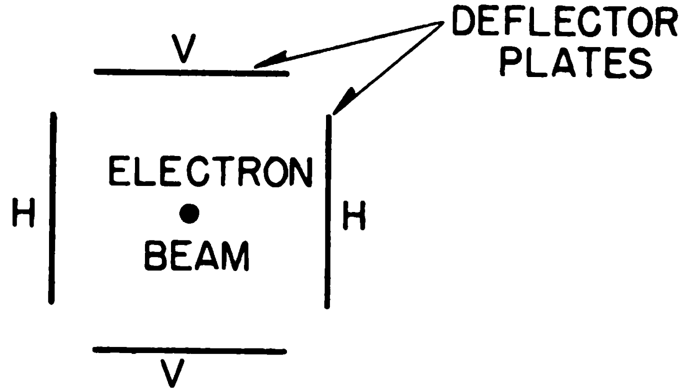


Figure 142.—Electron beam between neutrally-charged plates.

What will happen if you put EQUAL POSITIVE CHARGES on both the left-hand and right-hand plates at the same time? The beam will stand still at a spot at equal distance from each plate. But the instant that the positive charge on one of the plates is increased, the beam will move towards that plate. REMEMBER, electron movement is always FROM the NEGATIVE TOWARD the POSITIVE.

If a slow gradual increase of POSITIVE VOLTAGE is applied to one of the deflection plates, the spot on the screen will move slowly in the direction of that plate. If a sudden blast of positive voltage is applied to that plate, the spot will jump instantly in that direction. The beam of electrons is so light and so free to move that it can change direction thousands of times a second. That's why the electron beam is able to draw a picture on the fluorescent screen.

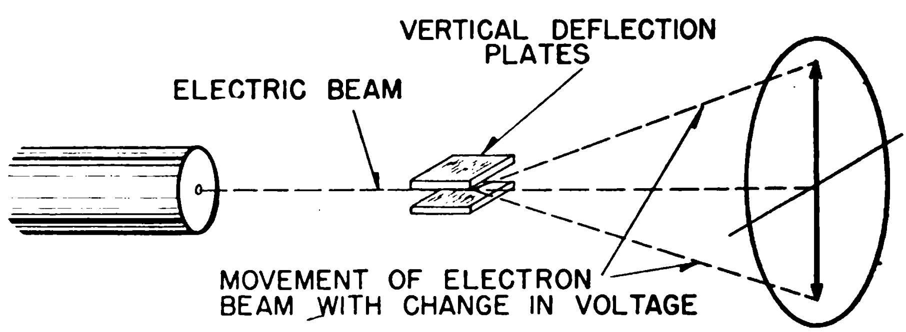


Figure 143.—Deflection by vertical plates.

If the movement of the spot is very slow, you can actually see it move. But, as its rate of movement increases,

it is no longer an individual dot—it becomes a solid line or TRACE across the screen. Thus the speed at which the spot moves, plus the persistance of the screen, causes the beam to draw a solid bright line.

The four deflection plates can work together to move the beam in various directions other than up-and-down and across the screen. By the correct COMBINATION OF VOLTAGES, at the right time, the beam can be made to travel in circles, squares, rectangles, and hundreds of other patterns. The shapes of these patterns are what you will READ when you use an oscilloscope to analyze a radio circuit.

CENTERING CONTROLS

All oscilloscopes have a device to keep the spot at the center of the screen when the deflection plates are idling.

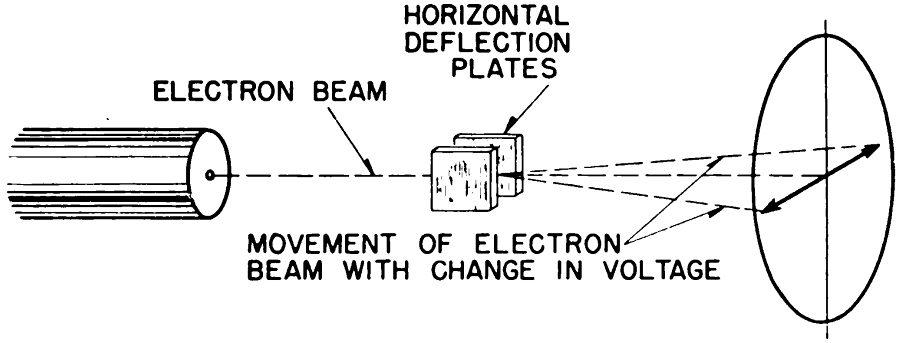


Figure 144.—Deflection by horizontal plates.

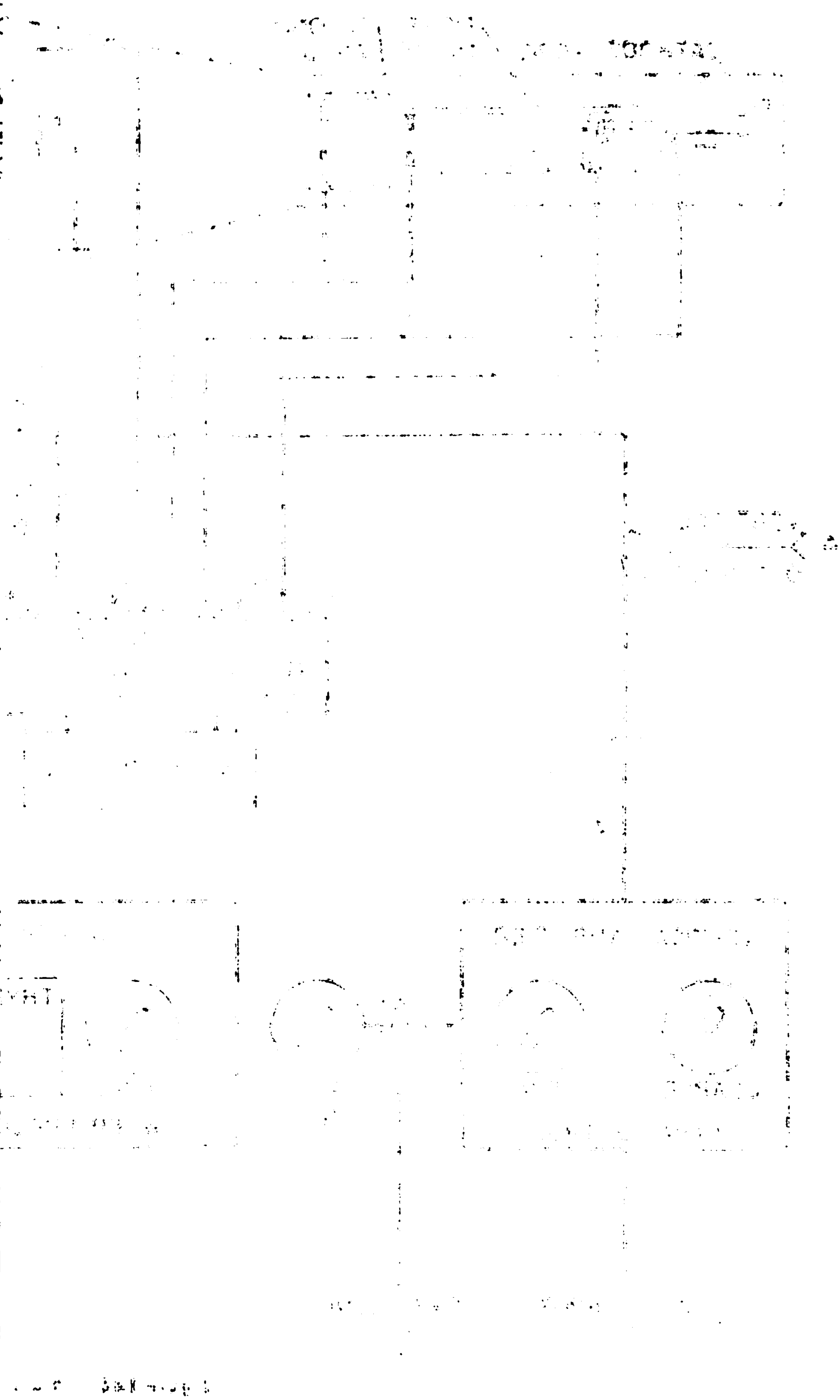
The dials regulating this device are called CENTERING or POSITIONING controls.

The oscilloscope has TWO of these positioning controls —one to locate the spot VERTICALLY equidistant between the top and bottom, and the other to set the spot HORIZONTALLY half-way between the right-hand and left-hand edges of the screen.

Figure 145 is a typical circuit used to center the electron beam. The POSITIVE terminal of the HIGH-VOLTAGE power supply is connected to the NEGATIVE terminal of the LOW-VOLTAGE power supply. This junction is also ground.

Two potentiometers P_1 and P_2 are connected in PARALLEL. These are in turn connected to points A and B.

Point A is BELOW GROUND potential, therefore is NEGATIVE. Point B is ABOVE GROUND potential, and is POSITIVE.



OTHER OSCILLOSCOPE CONTROLS

Thus far, only four oscilloscope controls—HORIZONTAL POSITIONING, VERTICAL POSITIONING, INTENSITY, and FOCUS—have been explained. In addition to these, most oscilloscopes have six other controls.

In figure 146, three new blocks—VERTICAL AMPLIFIER, HORIZONTAL AMPLIFIER, and SWEEP GENERATOR—containing the six new controls, have been added to the four controls you have already studied. Each manufacturer has his own names for these knobs, so the names given in this illustration are merely representative, not necessarily actual. Regardless of the names on your gear, their functions are the same.

VERTICAL AMPLIFIER

The vertical amplifier is a one-stage or a two-stage amplifier. Its purpose is to INCREASE the STRENGTH of the signal sufficiently so that the image formed by this voltage on the screen will be large enough for you to examine easily.

Most 5-inch-diameter cathode ray tubes require a potential of 100 volts to move the electron beam from the center to the edge of the screen. The voltages you wish to examine often will be less than one volt. You'll need the amplifier to build up these weak voltages to a point where they have enough energy to spread the image over the full screen, rather than have a small pattern at the center.

In figure 146, line *V* leads out of the vertical amplifier, passes through a condenser and a switch, and eventually reaches the upper vertical deflection plate.

The voltage or signal that you wish to "look at" is fed into the vertical amplifier at a-c input No. 1. The amplified voltage is carried out of the vertical amplifier through line *V* to the upper vertical deflection plate. The voltage appearing on this plate will cause the electron beam to move UP and DOWN, and draw a bright vertical line on the fluorescent screen.

The amount of up-and-down movement of the electron beam is REGULATED by two gain controls—COARSE and FINE. On your radio receiver, these would be called VOLUME controls, but since the oscilloscope DRAWS PICTURES, they are GAIN controls.

The names COARSE and FINE mean exactly that. One

control is a coarse ADJUSTMENT of the GAIN, and the other is a fine adjustment. Some oscilloscopes have these controls labeled with such names as ATTENUATION and AMPLIFIER GAIN, but their jobs are the same.

SWEEP GENERATOR

In figure 146, the block next to the vertical amplifier is the SWEEP GENERATOR. This generator is different from other generators you have studied—it has NO MOVING PARTS. Instead, it uses a special kind of vacuum tube called a THYRATRON—a type of TRIODE containing a small amount of XENON gas.

The voltage developed by an a-c power generator is SINUSOIDAL—it produces a SINE WAVE. That means that the voltage rises and falls at the rate shown in figure 147*A*.

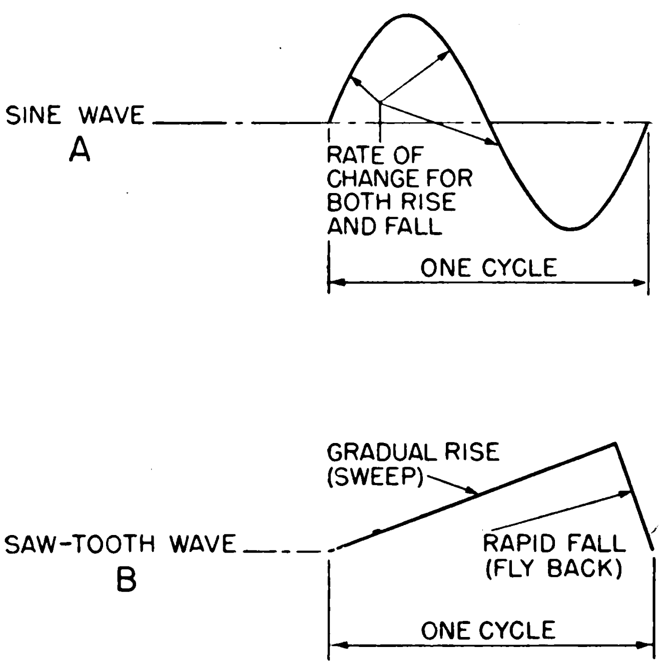


Figure 147.—Sine and sawtooth voltages.

But the voltage developed by the sweep generator is SAWTOOTH in character. Notice in figure 147*B* that the sawtooth voltage rises gradually and at a uniform rate. But instead of decreasing at the same rate, it falls ABRUPTLY back to the lowest voltage level, and then starts to rise again. This GRADUAL RISE and ABRUPT DROP gives the voltage curve a sawtooth appearance. The gradual rise is called the SWEEP, and the sharp decline is called the FLY-BACK.

A sweep generator also differs from a power generator in FREQUENCY. The average power generator operating at the correct speed has a frequency of 50, 60, or 120 cycles per second. The sweep generator used with most oscilloscopes is able to generate ANY frequency from 2 or 3 cycles up to 75,000 cycles per second.

The frequency of the sweep generator is regulated by two controls. The COARSE CONTROL selects the frequency RANGE, such as 4-to-10, 10-to-100, 100-to-1,000, and so on. The FINE control makes the adjustment for ANY INTERMEDIATE frequency within the range of each coarse control setting. For example—

You wish to use a 60-cycle sweep voltage. You will set the coarse control on the 10-100 range, then turn the fine control to the point where the CALIBRATION OF THE INSTRUMENT indicates that you get the desired frequency of 60 cycles. And—

If you desire a 500-cycle sweep frequency, turn the coarse control to the 100-1,000 cycle range, then adjust the fine control to the correct intermediate setting of 500 cycles.

The markings on the fine control are arbitrary numbers, usually from 1 to 10, which give you reference points. Before you can be sure that the frequency produced by the sweep generator is the frequency you want, you will have to check or CALIBRATE the sweep generator against KNOWN FREQUENCIES. Better not try to do this until you have been shown how by someone who knows what he's doing. A method of doing this calibrating is given in the training course for ETM 2c, Vol. II.

THE HORIZONTAL AMPLIFIER

The output of the sweep generator is not strong enough to operate the cathode ray tube correctly. The HORIZONTAL AMPLIFIER receives the OUTPUT of the sweep generator and amplifies this voltage before delivering it to the horizontal deflection plates. The horizontal amplifier has only one GAIN control which operates in the same way as the fine gain control of the vertical amplifier.

THE SWEEP

The sweep generator in an oscilloscope circuit generates a voltage that will move the electron beam ACROSS

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the screen at a UNIFORM RATE, and then make the beam FLY BACK INSTANTLY to the left-hand side of the screen, ready to SWEEP across the screen again.

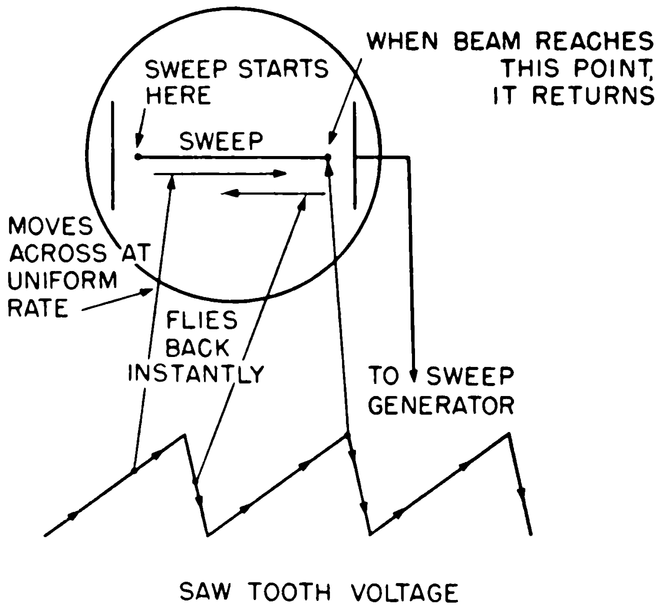


Figure 148.—Production of the horizontal sweep of a cathode ray tube.

Figure 148 illustrates the movements of the electron beam across the cathode ray-tube screen. The beam starts at the left-hand edge of the oscilloscope. The gradually-increasing POSITIVE voltage from the sweep generator is applied to the RIGHT horizontal plate. This rising potential will PULL the beam across the screen at a uniform rate until the abrupt break in the sweep voltage breaks-sharp. Since the right plate is no longer positive, the electron beam will fly back instantly to the left-hand side of the screen, and will immediately start another trace across the screen.

The NUMBER OF SWEEPS per second across the screen is the same as the FREQUENCY of the sweep generator voltage. If there are fewer than 15 sweeps a second, the actual movement of the spot can be seen. If there are more than 15 a second, the spot will draw a solid bright line.

Why doesn't the electron beam draw a line on the FLY-BACK? It does, but it is usually a weak one. At lower frequencies, the fly-back is so many times faster than the TRACE that the electron beam does not create a visible line.

But with sweeps of 50,000 per second and greater,

this is not true. At these high frequencies, you'll have to increase the INTENSITY of the electron beam in order to make it produce a visible image. And the fly-back time is now almost EQUAL TO the trace time. So the fly-back will draw a clear and visible line.

Fly-back traces are objectionable. They confuse the image you wish to study. Some oscilloscopes use a BLANKING CIRCUIT to cut-off the electron beam during the fly-back period.

WHY IS SWEEP NECESSARY?

If you place the voltage from a 60-cycle POWER LINE on the vertical amplifier with no alternating voltage on the horizontal plates, the image on the screen will be a VERTICAL LINE, as in figure 149*A*.

If you place the output from the 60-cycle sweep generator on the horizontal deflection plates, with no alternating voltage on the vertical deflection plates, you will get the image of figure 149*B*.

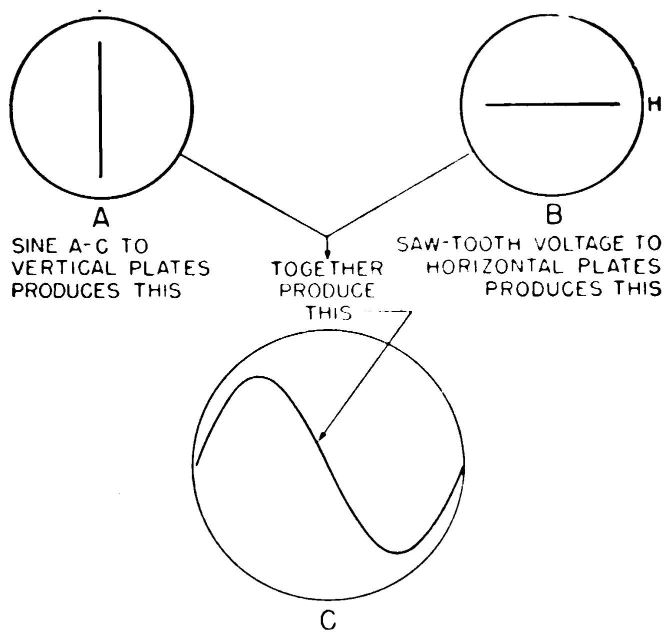


Figure 149. How a sine wave is produced on the screen.

Now put voltages *A* and *B* on the plates at the same time and you will get the image of figure 149*C*—a SINE WAVE.

In figure 149*A*, all the up-and-down movements of the sine wave are present, but since these movements retrace themselves over and over on the same line only one bright

trace is produced. Now add the HORIZONTAL sweep voltage to the cathode-ray tube. The up-and-down motion of the sine wave is spread across the face of the screen, and each separate rise-and-fall of the wave will show up.

If the VERTICAL AMPLITUDE of the image to be viewed is too small, turn up the VERTICAL gain control. To increase the WIDTH of the image, turn up the HORIZONTAL gain control.

SYNCHRONOUS CONTROL

The SYNCHRONOUS CONTROL—SYNC. CONT., figure 146—is used to make the image STAND STILL on the screen. This unit takes a small amount of voltage from the vertical amplifier and feeds it into the sweep generator. This voltage helps control the frequency of the sweep generator, and keeps the intervals between traces exactly the same. The SYNC. CONT. regulates the amount of voltage that is taken from the vertical amplifier and fed into the sweep generator.

OTHER ATTACHMENTS AND SWITCHES

All oscilloscopes are equipped with a number of JACKS, CONTROLS and SWITCHES that permit you to connect sources of voltage directly to the deflection plates without first going through the amplifier. A number of these attachments are shown in figure 146. The use of these special devices requires a more advanced knowledge of the oscilloscope than you now have. Leave them alone until you learn to use them. The manuals for ETM 2c will tell you how.

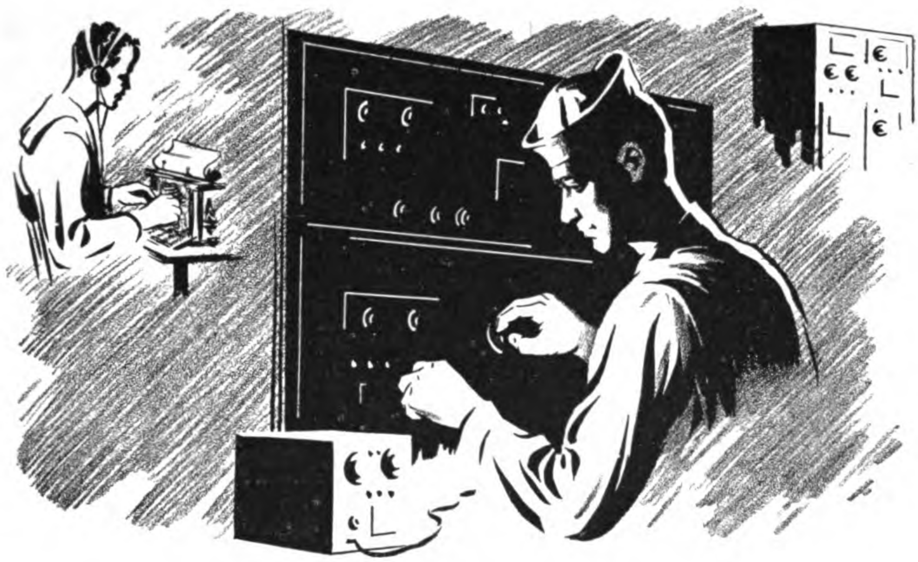
JOBS FOR THE OSCILLOSCOPE

Now that you know all the controls, what they do, and how they work, you are ready to use the oscilloscope. To use it correctly as a precise scientific instrument requires practice and study. Get a chief or some other expert to demonstrate the correct procedures. Here are a few jobs you can do with the oscilloscope—

Study and look at wave forms from all types of generators.
Measure modulation percentage.
Check for distortion in amplifiers.

Check receiver for dead spots.
Detect current and voltage surges.
Aline resonant circuits.
Determine vacuum tube characteristics.
Compare wave shapes.
Measure voltage and current values.
Use in radio direction finding.
Make frequency determinations.
Make phase determinations.

And there are hundreds of other uses. The more you work with the cathode-ray oscilloscope, the more jobs you will find for it.



CHAPTER 18

REMOTE CONTROL SYSTEMS

WHY USE THEM?

Usually the radio transmitters and receivers are located a considerable distance away from the operator's station. The CIC—COMBAT INFORMATION CENTER—of a carrier is a good example of this. At the CIC, the FIGHTER DIRECTOR OFFICER—FDO—is in constant contact with the fighter squadrons, receiving reports from them and giving orders to direct their operations. You seldom find the TBS transmitter installed in the CIC under the FDO's thumb, and yet he must be able to control the transmitter without leaving his station. REMOTE CONTROL is the answer.

The compartments where the transmitters and receivers are actually installed vary with the class of ship and the modifications that have been made to its basic design. On a BB or a CV, the transmitters are usually several decks below. On a DD or a DE, the transmitters and receivers may be on opposite sides of a bulkhead on a superstructure deck.

Remote control systems not only eliminate the wasted energy of rushing below to start and stop the transmitter each time a message is to be sent, but they also permit the radio equipment to be operated from several control points about the ship.

With remote control, the operator can use either code

or voice, can switch from one transmitter or one receiver to another, can start, stop, or key the transmitter, and can handle a number of other tasks necessary to maintaining communication—all without going near the transmitter room.

WHAT IS REMOTE CONTROL?

All of these operations are not completely automatic, and cannot be done merely by punching buttons. Several of them require the aid of an ETM or RM to switch the PATCH CORDS on the TRANSFER PANELS, TUNE the receivers, transmitters, and make several other necessary operating adjustments.

TYPICAL PARTS

Remote control systems on all Navy ships follow a general pattern. The systems installed in a BB or CA have many circuits. Those on a DD may have the same variety or parts, but won't have as many duplicate pieces of equipment. The installations can be compared to the telephone systems in a large city and a small town. Both systems have the same parts—desk sets, switchboards, wires, and the like—but the larger city will have a greater number of each of these parts.

In figure 150, you see a typical remote control system that you will find installed in Navy ships. The circuits handle one transmitter, receiver, and remote station. If additional transmitters, receivers, and remote stations are used, the extra units and circuits will be DUPLICATES of these shown.

In addition to the two major units—the TRANSMITTER and the RECEIVER—a remote control system has a number of other parts. In figure 150, the RECEIVER UNIT is in the lower left-hand corner. A KEY CONTROL PANEL is next to the receiver. From this panel you can start, stop, and key the transmitter.

A JACK BOX with a receiver OFF-ON switch is connected to the receiver OUTPUT. The box has two outlets so that you can use two sets of headphones.

Another key control panel and jack box are indicated in the upper left-hand corner. This suggests to you that several of these units may be installed at various stations in the ship.

The transmitter VOICE-AMPLIFIER-MODULATOR unit is in the lower right-hand corner of figure 150.

The FREQUENCY METER between the transmitter and receiver units is used to check the frequency of the transmitter.

In the upper right-hand corner of figure 150 is a RADIOPHONE UNIT, with the controls for maintaining both voice and C-W communication.

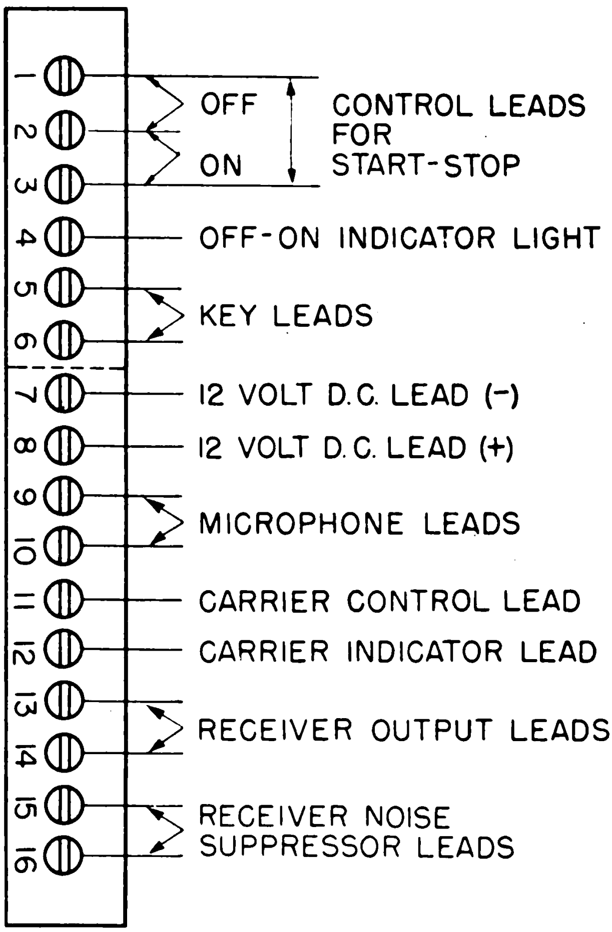


Figure 151.—Identification of contacts on terminal strips.

Three transfer panels—RECEIVER, TRANSMITTER, and RADIOPHONE,—extend across the center section of the illustration. These panels are switchboards, similar to those used with telephone circuits. The ETM or RM who mans these boards can switch from one transmitter or receiver to another by pulling the patch cords out of one jack and inserting them in another jack.

CONNECTING CABLES and TERMINAL STRIPS make up the rest of the remote control system.

TERMINAL STRIPS

Terminal strips are pieces of bakelite or other insulating material fitted with binding posts. Each binding post has an identifying number.

The binding post numbers and their associated connections are given in figure 151. Not every remote control unit will use all 20 terminals, but the numbers and the associated circuits are not switched. The key control panel has six contacts, numbered from 1 to 6. Terminals 1, 2, and 3 carry the ON-OFF, MOTOR-START, and MOTOR-

KEY CONTROL PANEL

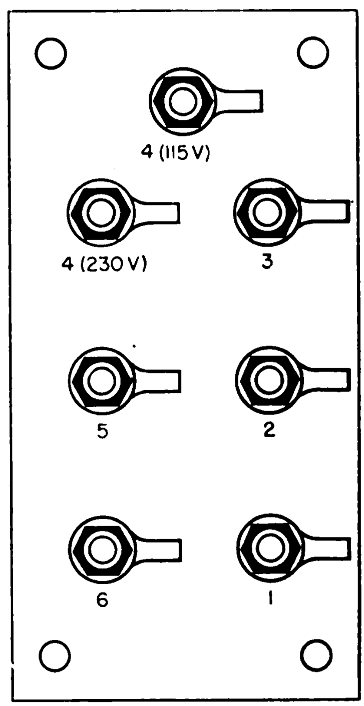


Figure 152.—Key control panel. (Bottom view.)

STOP leads. Terminal 4 handles the POWER OFF-ON indicator light, and 5 and 6 are the KEY LEAD terminals.

The radiophone transfer panel terminal strip has ten contacts, numbered from 7 through 16. Number 7 is the 12-volt d-c NEGATIVE CONTACT, terminal 8 is the 12-volt d-c POSITIVE lead. Contacts 9 and 10 are for the MICROPHONES, and so on for the remaining leads.

Learn to associate the terminal number with the circuit involved. It will save you a lot of time when you are installing or repairing a remote control unit.

The terminal strips do not always have their contacts

arranged in a straight line. Some strips are arranged as you see them in figure 152. This strip is a key control panel as you see it from the bottom.

Figure 153 is a top view of a key control panel. This unit is mounted so the surface of the panel is FLUSH with the top of the operator's desk.

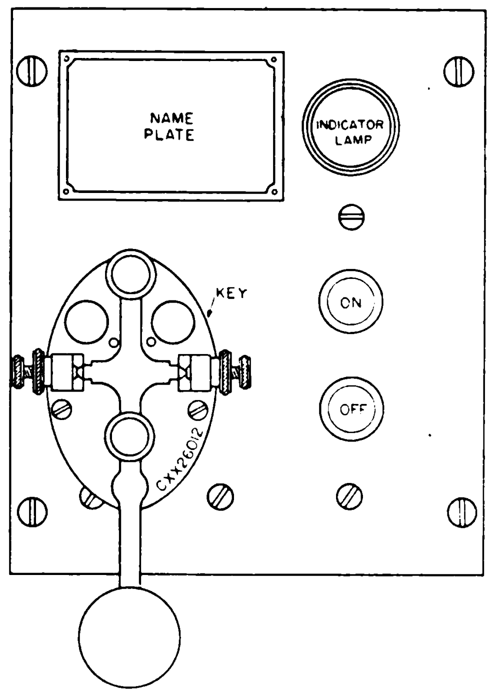


Figure 153.—Key control panel. (Top view.)

The internal connections of the key control panel for a standard 6-wire circuit are given in figure 154*A*.

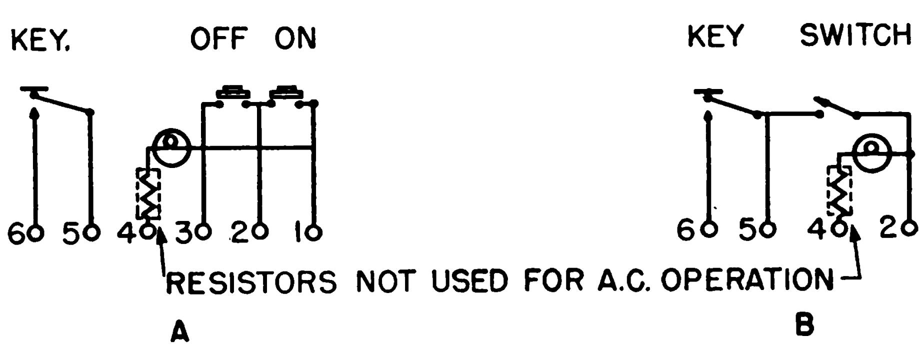


Figure 154.—Four-wire and six-wire remote control system.

Figure 154*B* shows how the 6-wire system can be changed to operate as a 4-wire control. Notice that wires 1 and 3 are omitted.

The OFF-ON switch of a 6-wire system is the MOMENTARY CONTACT type—similar to a doorbell push button.

The switch is closed as long as you keep your thumb on the button, but opens when the pressure is released.

The OFF-ON switch used with a 4-wire system is a single-pole single-throw continuous-contact switch.

The resistor in the indicator-lamp circuit limits the current flowing through the bulb when a potential of 230 volts is applied to the starter circuit. When you are using 115 volts, short-out the resistor with a jumper.

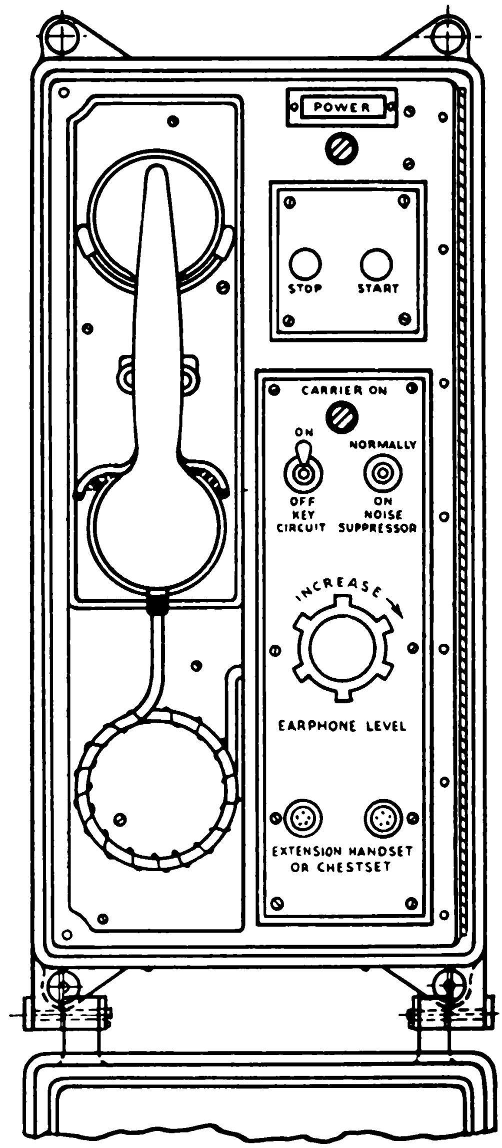


Figure 155.—A water-tight radiophone unit.

RADIOPHONE UNIT

Figure 155 illustrates the front panel of a radiophone unit. The unit is provided with a cover that is water-tight when closed and locked.

The radiophone has a combination microphone-and-receiver, similar to a handset telephone. When not being used, the handset is held in place on the unit by a clamp hook. When you remove the handset from the hook, a switch is closed, just as it is when you pick up the handset of a regular telephone. The "CARRIER-ON" bulb lights up when the handset is removed from the hook, indicating that power is being applied to the handset.

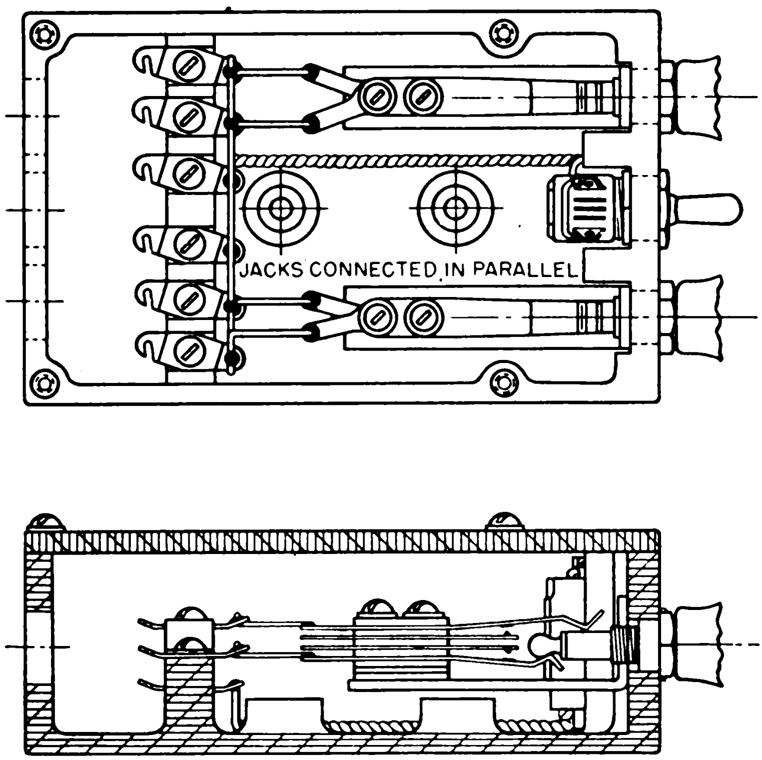


Figure 156.—Jack box with switch.

The intensity of sound produced by the earphone is regulated by the knob marked "EARPHONE LEVEL," near the center of the panel.

Two plugs for 5-tip jacks are mounted at the bottom of the panel. These are for use with EXTENSION HANDSET or CHESTSET phone.

The KEY CIRCUIT OFF-ON switch is used only when you wish to send a C-W message instead of a voice message. The key is a separate unit and may be installed some distance away from the RADIOPHONE unit.

The NOISE SUPPRESSOR is normally ON. This device reduces the level of the audible message, as well as the level of the noise. When the messages are at low-level intensity, you PRESS the button to CUT-OUT the noise suppressor so

that the message will be stronger. When you release the button, the noise suppressor is automatically CUT-IN to the circuit.

The POWER START-STOP button arrangement is just the same as on the key control panel.

JACK BOXES

Two types of JACK BOXES are used with most remote control systems. The type with a switch, identified by number 49029 in figure 150, is shown in figure 156.

The other jack, identified in figure 150 by number 49063, is shown in figure 157. This type has six jacks, but no switch. It is used in figure 150 to connect the frequency meter to the transmitter.

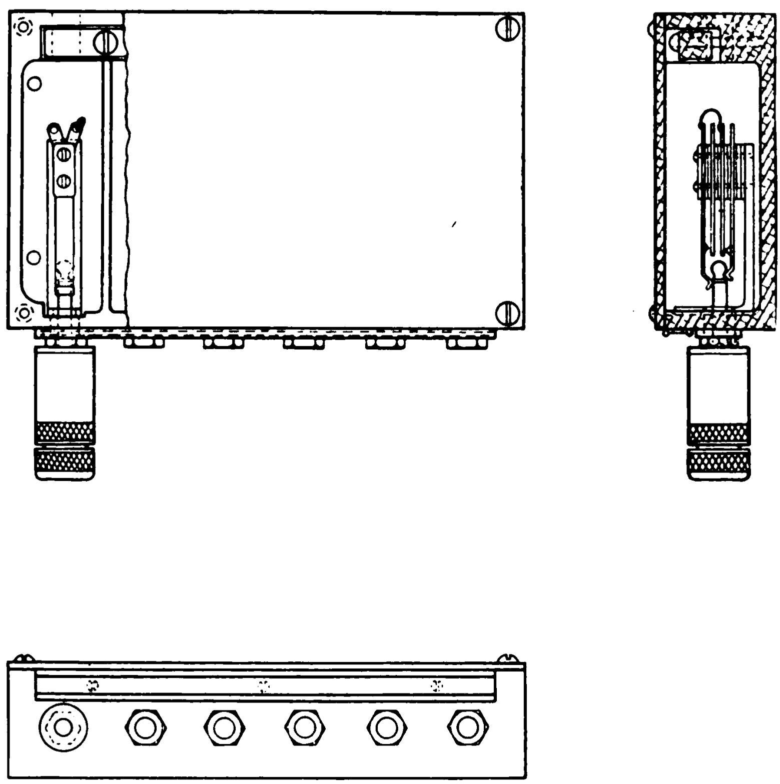


Figure 157.—Shielded jack box.

TRANSFER PANELS

Transfer panels are sheets of bakelite or some other insulating material equipped with jacks or sockets to accommodate the patch cord plugs.

The RECEIVER transfer panel uses jacks of the type shown in figure 158. At each end of the cords is the type of plug shown in the same illustration.

If the operator at the radiophone unit in figure 150 wishes to check the frequency of the transmitter, he will insert one end of the patch cord in jack *C* and the other end in jack *I*.

If the operator wishes to cut-in on the receiver, he will plug one end of the patch cord into jack *H*, the other end into jack *C*.

The transfer panels for the TRANSMITTER and RADIOPHONE unit are slightly different from the receiver panel. The SOCKETS resemble vacuum tube sockets. The PLUG is similar to the base of a vacuum tube. The plug is prevented from slipping out of the socket by a COLLAR that fits over the plug and screws tightly to the base.

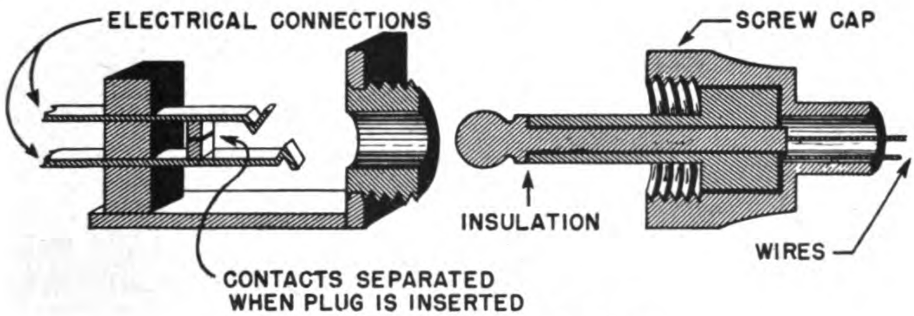


Figure 158.—Two-contact plug.

The spacing and the size of holes in the sockets prevent you from inserting the plug into a socket incorrectly.

CABLES

The connecting wires and cables are important parts of a remote control system. The number of wires and the structure of each cable is described by such letters as MHFA-7 or TTHFA-1. If you have forgotten what these letters mean, turn to the appendix of the training course on BASIC ELECTRICITY and review them.

THE RELAY

The relay is the device that really makes a remote control system work. You first heard about the relay in BASIC ELECTRICITY. Here is a review of its principles.

Figure 159 is a BASIC RELAY CIRCUIT. When switch *SW* is closed, the electromagnet is energized and pulls the armature TOWARD the core of the magnet. When this happens, the contacts on the armature close the circuit and turn on the light.

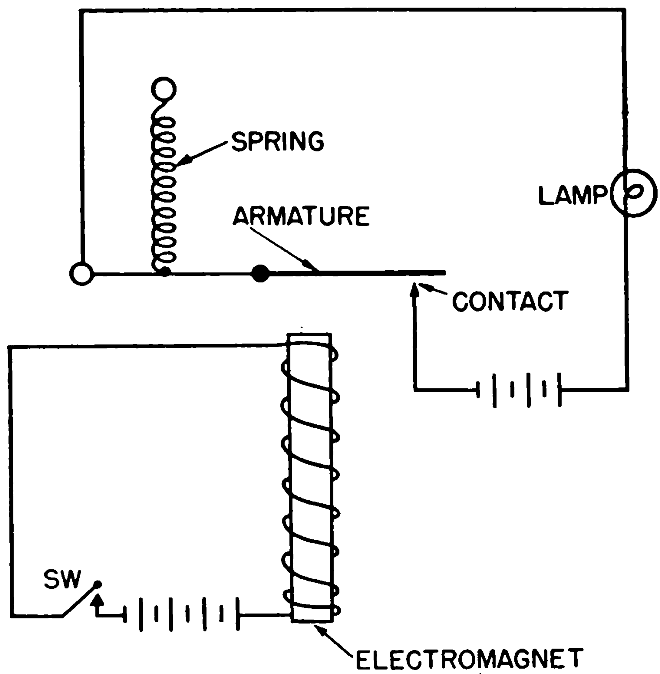


Figure 159.—Basic relay circuit.

The relay in figure 159 is a single-contact single-acting type. In addition to this type, the Navy uses many multiple-contact and multiple-pole relays. Figure 160 shows four relays.

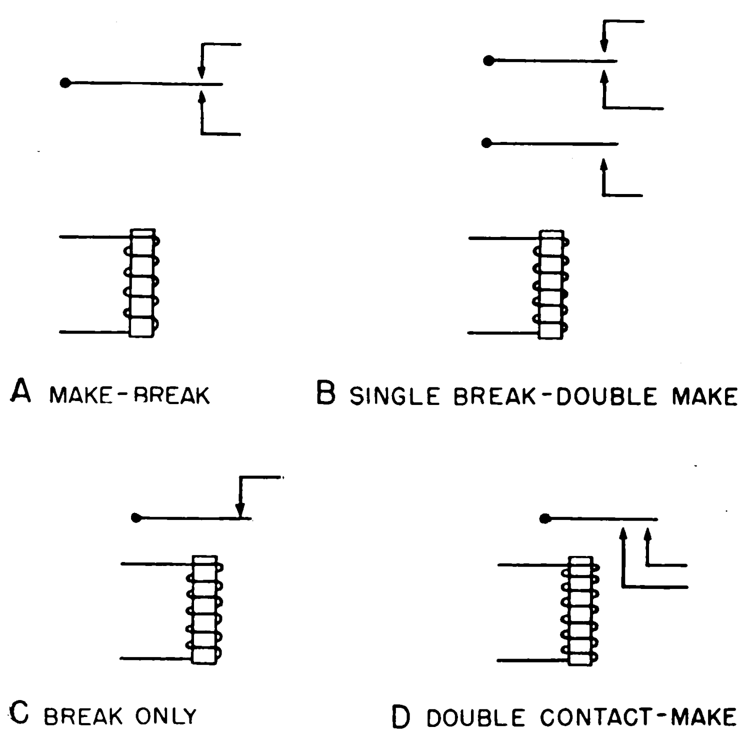


Figure 160.—Types of relay contacts.

Some relays have the armature attached to a MOVABLE CORE, as in figure 161, while others are the CLAPPER type. Many combinations of these two types have been made.

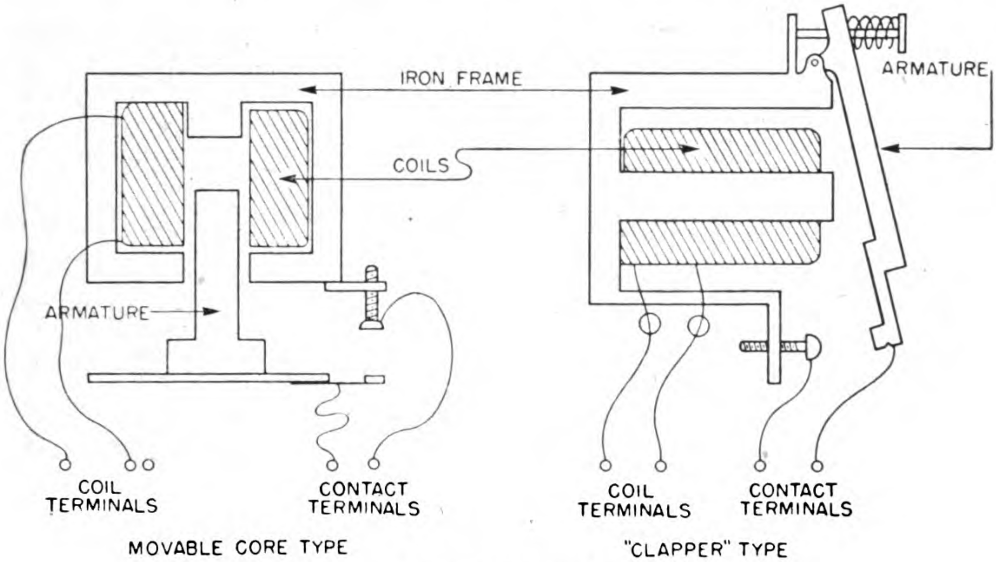


Figure 161.—Types of magnetic contactors.

Relays may be excited either by a.c. or by d.c. If a.c. is used, the core is modified slightly to prevent the armature from CHATTERING.

The core in figure 162 is NOTCHED to form a large segment *A* and a smaller segment *B*. Segment *B* is the SHADING POLE and has a band of copper *C* wrapped around one end.

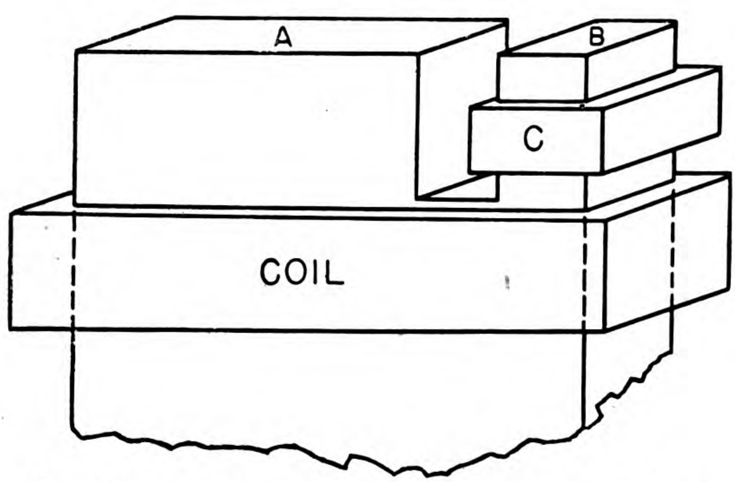


Figure 162.—Shading pole, used with a-c excited relays

The CHANGING FLUX caused by the a.c. in the main coil induces a HIGH CURRENT in the low-resistance copper

band. This induced current LAGS the current in the main coil. Hence the flux set up by the induced current lags the flux produced by the MAIN COIL. This arrangement prevents the COMBINED FIELDS of poles A and B from ever reaching ZERO INTENSITY. Thus the holding force is never relaxed, and the armature is held tight against the core at all times.

RELAY CLASSIFICATION

Relays used with Navy radio equipment are divided into three classes—OPERATIVE, PROTECTIVE, and CONTROL, —according to their use. The wide variety of applica-

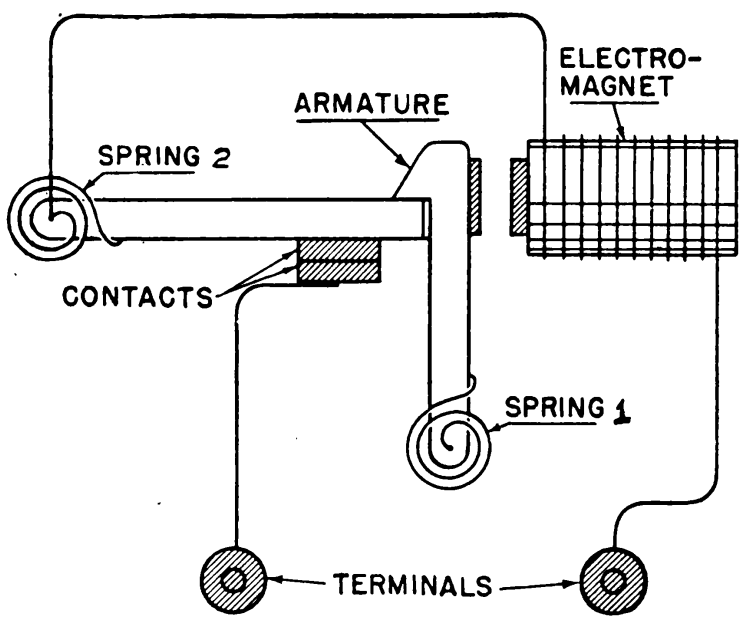


Figure 163.—Instantly-opening manual-reset overload relay.

tions is responsible for the many modifications in the basic design of the relay. You will not find all types used in a single set, but you will always find a few.

KEYING RELAYS

OPERATIVE RELAYS are those used to KEY a transmitter circuit. They may have either movable core or clapper-type armatures. The contacts are of the types shown in figure 159 and 160. The specific design to be used with a transmitter depends upon what method of keying is employed. You will learn more about these relays when you study transmitters.

PROTECTIVE RELAYS

A protective relay protects a piece of electrical gear from damage that may be caused by excessive current drainage. Some relays are designed to break the circuit INSTANTLY, others have TIME-DELAY features that will permit small overloads for short periods of time. Still others are designed to DELAY the turning-on of a high voltage until a certain length of time has elapsed.

OVERLOAD RELAYS

Figure 163 shows one type of INSTANTLY-OPENING overload relay. This relay is connected IN SERIES with the load. When the current flowing through the coil of the electromagnet rises above the normal value, the pull of the magnet will overcome the tension of spring 1, and will draw the armature toward the core. This action permits the contacts to fly open, breaking the circuit.

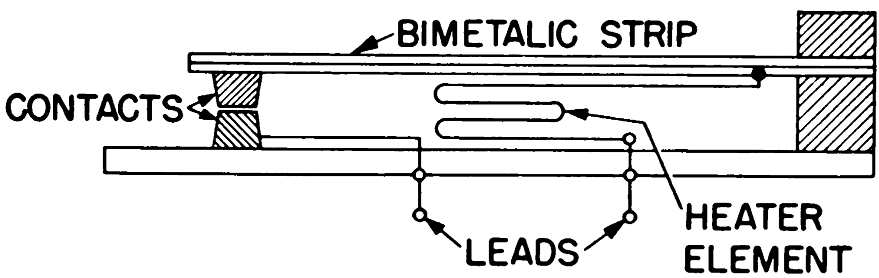


Figure 164.—Thermal overload relay.

This particular relay is a MANUAL RESET type. Once the circuit has been broken, you have to push a button to reset the contacts together again.

Some relays reset AUTOMATICALLY. These are used with other controls which keep the power off, once the circuit has been broken. You will find this type common in some motor-starter circuits.

The instantly-opening relay can be converted to an INVERSE-TIME-DELAY RELAY by connecting the plunger of an OIL DASHPOT to the armature. The dashpot consists of a cylinder and a plunger. The cylinder is filled with oil. The inside walls of the cylinder are grooved—NARROW grooves at the bottom, the grooves becoming WIDER towards the top.

When the circuit is operating normally, the plunger is at the bottom of the cylinder. A slight OVERLOAD CURRENT

will pull the armature and the plunger upward. The initial movement is slow, but becomes more rapid as the plunger reaches the wider portions of the grooves. If the overload continues, the plunger will eventually reach the top, permitting the armature to release the contacts and break the circuit.

THERMAL OVERLOAD RELAYS

The THERMAL OVERLOAD RELAY does not use an electromagnet. Instead, the relay movement is made up of two thin strips of two different metals welded together back-to-back over their entire length. One of the metals must have a higher rate of expansion than the other. Usually one strip is brass, the other is steel.

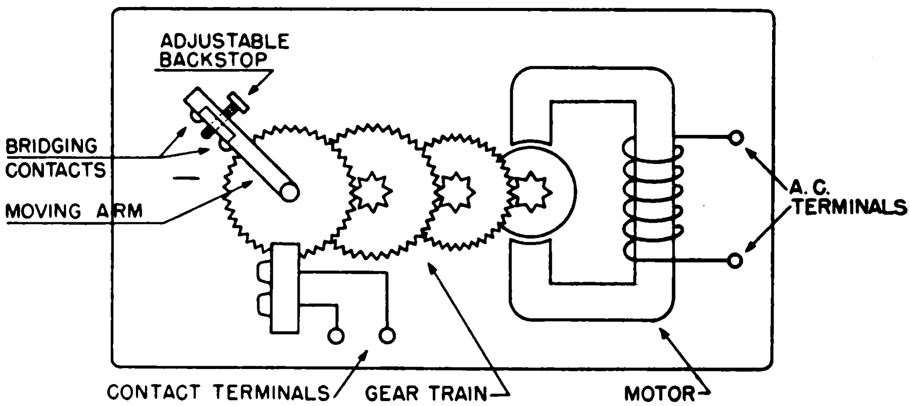


Figure 165.—Gear-train time-delay relay.

One type of thermal overload relay is shown in figure 164. The metal with the highest rate of expansion is BRASS, and is on the bottom.

When the circuit becomes overloaded, the overload current flowing through the circuit heats the resistance, indirectly heating the bimetallic strip. The greater rate of expansion of the lower metal strip—the brass—will cause the bimetallic strip to BEND UPWARD. The bending breaks the contact and opens the circuit. These relays are usually called THERMOSTATS.

DELAYED ACTION RELAYS

The DELAYED-ACTION RELAY postpones the closing of a circuit for a certain number of seconds after the operating button is punched. Its action is not dependent upon the overloading of a circuit, as is the case with the inverse-time-delay relay.

Figure 165 shows one form of TIME-DELAY RELAY. It is actually a small 600-rpm, self-starting synchronous motor with a train of reduction gears.

As long as this motor is not energized, the armature is not in contact with the gears. When an a-c voltage is applied to the motor—by pushing the circuit START button—the flux of the stator pulls the armature INTO MESH with the gears.

The motor starts turning and drives the gear train forward, moving the MOVABLE ARM. After a selected period of time, the contacts on the movable arm reach the FIXED contacts and close the circuit.

When the contacts close, the motor STALLS. This motor armature is designed to remain stalled without damage to itself. The TORQUE action created by the field holds the armature in mesh with the gear train, providing a constant pressure to KEEP the contacts closed.

If the energizing voltage fails, the armature falls OUT OF MESH and a recoil spring rolls the gears back to their original position, opening the contacts. The TIME OF DELAY is regulated by adjusting the back-stop screw, or by changing the gear ratios.

TIMETRACTOR

Another common type of delayed-action relay is the TIMETRACTOR. Figure 166 is a sectional view of a timetractor.

The pole piece is IRON, surrounded by a COPPER cylinder. There are two coils—MAIN and NEUTRALIZING—wound in OPPOSITION to each other.

When an energizing voltage is applied to the main coil, the armature is pulled toward the pole piece, breaking the MAIN CONTACTS. This action also opens a pair of auxiliary contacts, de-energizing the main coil. The magnetic field begins to DECREASE, inducing a HIGH CURRENT in the copper cylinder. This current permits the magnetic field to decay at a very slow rate. The decay will continue until the force of the kick-out spring is greater than the holding force of the magnet. The armature will then fly back and close the main contacts.

Usually the decay of the field is too slow—it may last for hours. However, if the neutralizing coil is energized through another set of auxiliary contacts, the rate of de-

cay is increased. By controlling the amount of current that flows through the neutralizing coil, the length of time required for the relay to act can be set for a predetermined value.

The timetractor is used to SHORT-OUT the starting resistence that is inserted in series with the armature of

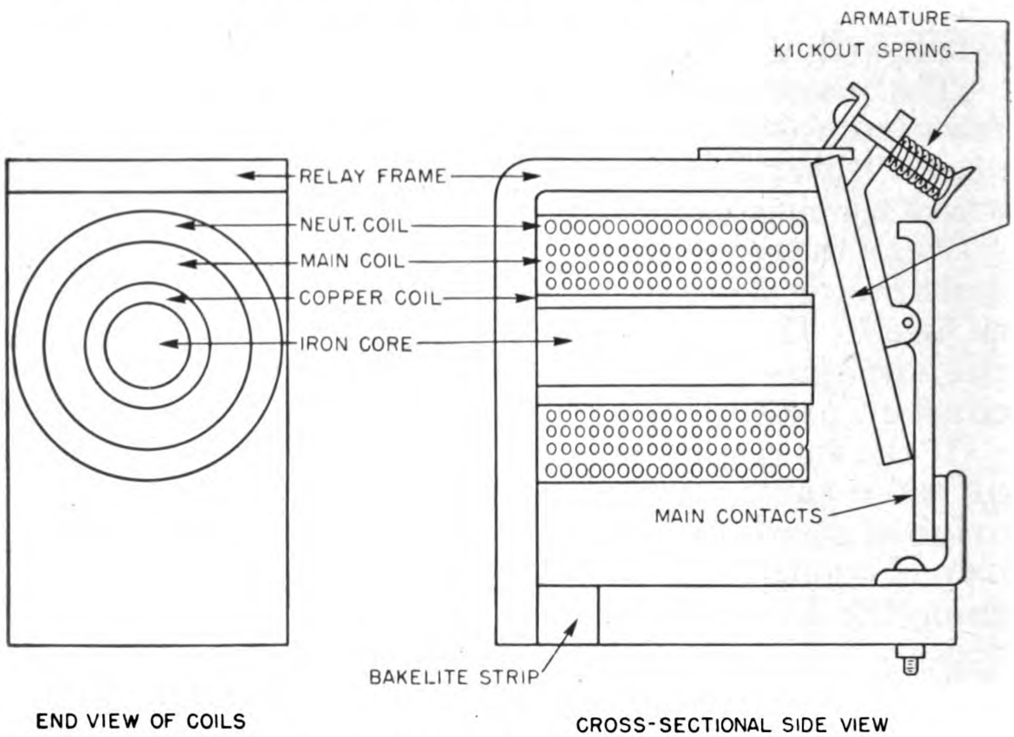


Figure 166.—Timetractor relay.

a motor while the motor is building-up speed. The magnetic controller included in figure 167 contains one of these relays.

CONTROL RELAYS

Control relays are used to START and STOP electric motors. The heavy relay that actually applies the power to the motor is the MAIN LINE CONTACTOR. The relays that control the main-line contactors are usually SERIES or SHUNT RELAYS. All of the relay units are referred to collectively as MAGNETIC CONTROLLERS.

Usually the series-shunt relays and contactors follow a step-up arrangement. A small relay is energized by a small, manually-operated switch. This small relay closes a larger relay, which in turn energized the main-line contactors and other devices necessary to start and keep the motor running.

There are many types of magnetic controller circuits. Figure 167 is representative of the type used with several Navy transmitters.

The START-STOP buttons may be at some remote station on the ship. The other controls are mounted near the motor.

The sequence of events that occurs from the time the start button is pressed until the motor is running at full-speed is given in figure 168. Follow the arrows. They show the way.

When you wish to turn off the motor, press the STOP button. This shorts out the MASTER STARTER RELAY and removes the holding force on contacts. Contact CA_2 opens. This in turn de-energizes the other relays, opening contacts CB_1, CE_3, and CE_4. This stops the motor.

The OVERLOAD RELAY COIL (RO) is in SERIES with the motor. When an abnormally high current flows through

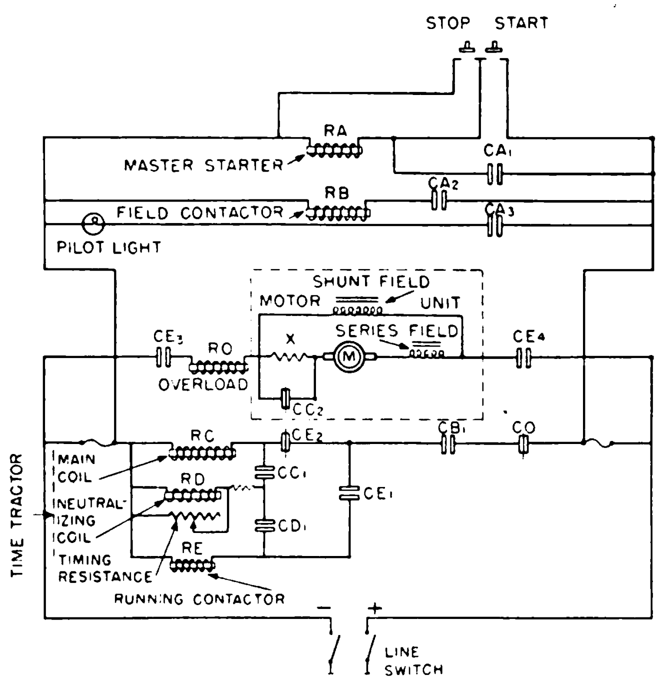


Figure 167.—Magnetic controller circuit for a d-c motor.

the motor, the MANUAL RESET CONTACT (CO) opens, shutting off the power to the motor.

ARCING AT CONTACT POINTS

When the contacts supplying power to the motor are broken, a heavy surge of current will create an arc and burn the contacts. This arc is much more destructive to

contacts if the break is "sloppy," or if the contacts have a tendency to linger near each other after the circuit has been broken.

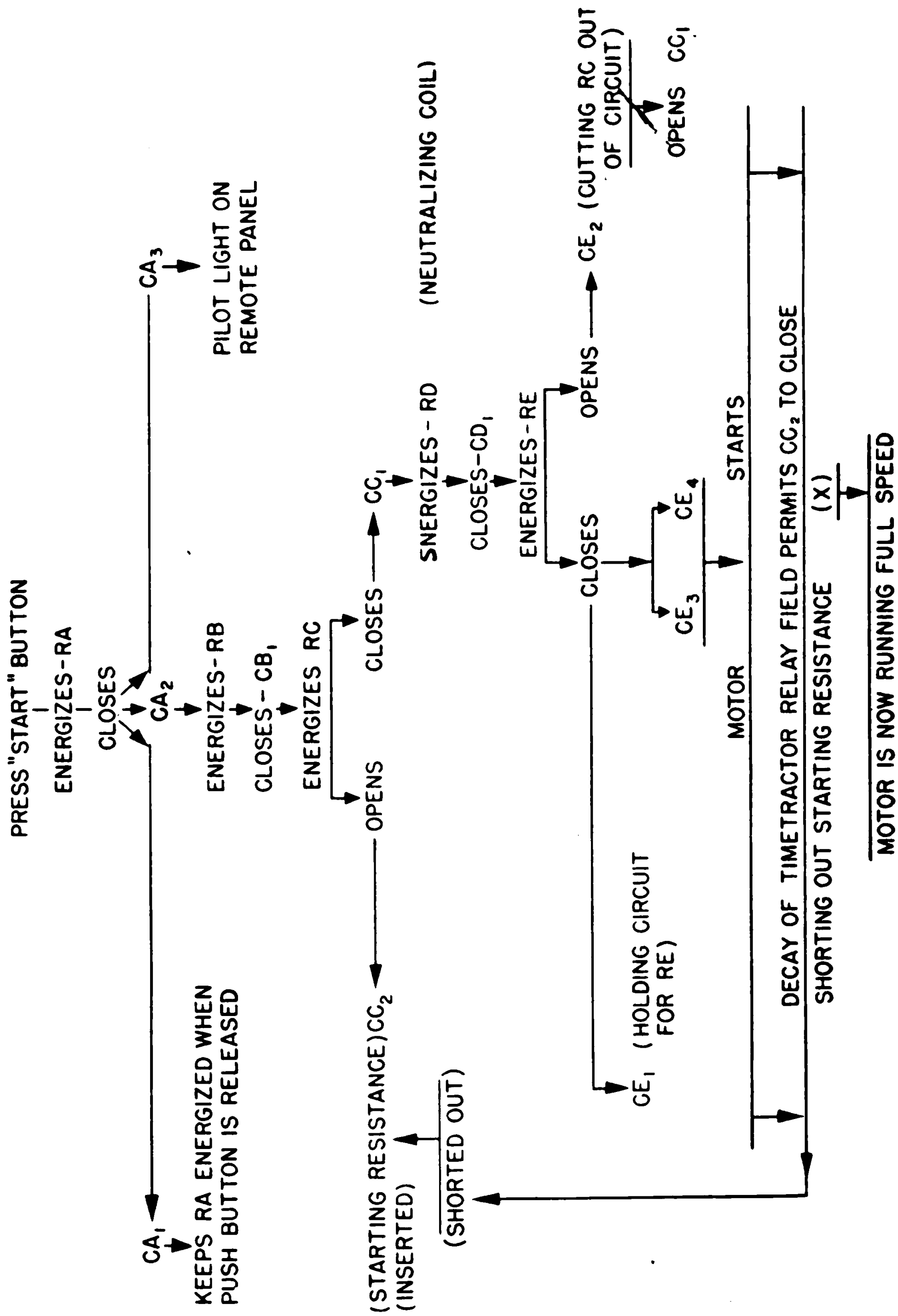


Figure 168.

Numerous methods are used to prevent arcing or to reduce the damage done by the arc. One method mounts the contacts on a PIVOT. The pivot gives the contacts a

WIPING action when either opening or closing. A firm, positive, rapid connection is assured when the circuit is made, and a sharp break is produced when the circuit is opened.

Some relays use a device known as a BLOW-OUT COIL. This consists of a few turns of wire on an iron core, the coil connected IN SERIES with the load.

The arc created by the opening of the contacts produces a magnetic field similar to the field produced by a conductor which is carrying a current. The field produced by the blow-out coil is carried by the ARCING SHOES from the iron core to each side of the contact. This field shoots across the contacts IN OPPOSITION to the field produced by the arc. The combined effect of the two fields results in BLOWING-OUT the arc before it is able to pit the contacts.

Copper oxidizes and forms a highly-resistant film on the contacts. This insulating effect is lessened by silver-plating the surfaces of the contacts since silver oxidizes less rapidly.

Another method of reducing arcing uses TWO PAIRS of contacts—one large, the other small—connected IN PARALLEL. When the circuit is being opened, the large contacts separate first without arcing, and the small contacts remaining closed. The higher resistance of the small contacts REDUCES the total current flowing through the circuit, so that when these contacts separate—after the large contacts are fully open—a much smaller arc will be produced.

Care of the contacts is the major service required by relays. If the contacts have become PITTED, use a fine file to smooth them down. Never file them any more than is necessary. Remember, keep them smooth. Contacts must be replaced when the filing has cut down through the silver to the copper or brass undermetal.

Use CARBON TETRACHLORIDE to clean contacts. Be sure to wipe them off with a chamois or a LINTLESS cloth.

SEQUENCE—CLOSING RELAY SYSTEMS

Many circuits require that the voltages be turned on in the proper order. The grid and plate circuits of a transmitter are examples of this. If the plate potential is turned on before the grid voltage, the tube may be dam-

aged by the excessively high current. In figure 169, the potential applied to the grid circuit closes the plate circuit. If anything happens to make the bias voltage fail, the plate circuit will open, preventing damage to the tube.

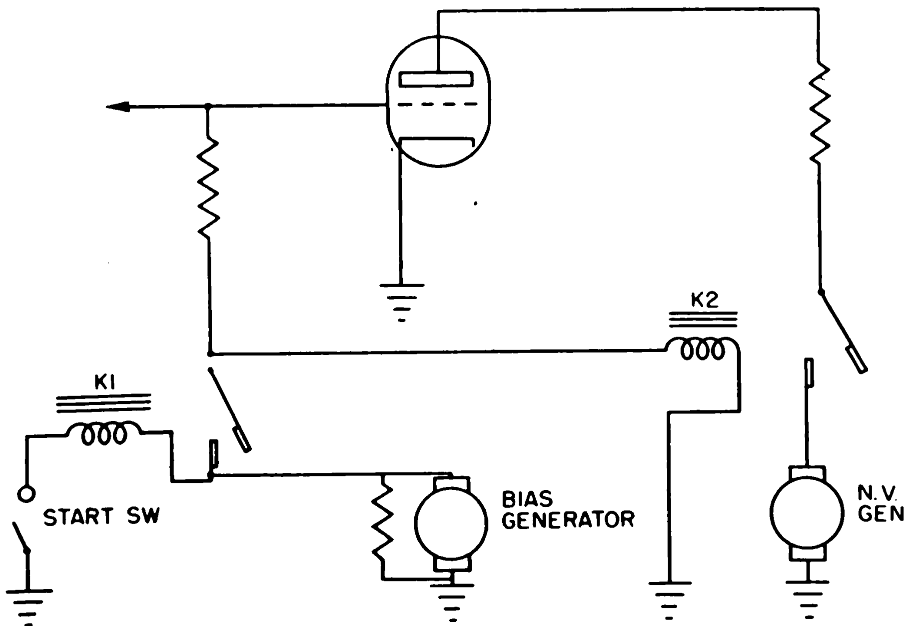


Figure 169.—Sequence closing relays used with grid and plate circuits.

THE FIRST LAP

You now have completed the first lap in becoming an Electronic Technician. The knowledge of how well you have learned your job can be gained partially by testing yourself with the questions in the quiz section of this manual. However, the real test is not what you can do with a pencil, or how well you can remember the correct answer, but in how efficiently you do the jobs assigned you in keeping the radio gear in good condition.

When you have passed your examinations and received your rate, go on and study the manuals for Electronic Technician 2c. You have a good start. Keep going!

How Well Do You Know The Duties Of An—

ELECTRONIC TECHNICIAN'S MATE 3c

QUIZ

CHAPTER 1

INTRODUCTION TO RADIO

1. Energy from the transmitter passes to the receiver by means of (electrostatic) (electroagonic) (electromatic) (electromagnetic) fields in the ether.
2. What is generated when an electric spark jumps back-and-forth—oscillates—between two electrodes?
3. A transmitter antenna serves what useful purpose—(to provide an atmospheric ground) (to radiate electrostatic energy) (to radiate electromagnetic energy) (to radiate actinic rays)?
4. List the five functions of a receiver.
5. (*a*) What is the ether? (*b*) What purpose does it serve in radio?
6. Carrier waves (are) (are not) the same as radio waves.
7. Radio waves travel (164 feet per second) (164,000 nautical miles per hour) (164,000 land miles per second) (164,000 nautical miles per second).
8. (*a*) How many CYCLES in 10 kc.? (*b*) in 15.4 Mc.?
9. A normal human ear can hear sounds that lie in the range (20-20,000 cycles per second) (3.1416-348 cycles per second) (19.45-1066 cycles per second) (181,200-5,440,000 cycles per second).
10. Commercial radio broadcasts are transmitted on which band of frequencies—(240-1810 megacycles) (550-1600 kc.) (55-160 kc.) (550-1600 megacycles)?

CHAPTER 2

CURRENT AND VOLTAGE

1. Current is a _____?_____ of electrons (from) (toward) the positive pole.
2. In the law of likes and unlikes, positive objects (attract) (repel) positive objects, while position objects (attract) (repel) negative objects.
3. A gas must be (ozonized) (iodinized) (neonized) (ionized) before it will conduct current.
4. What is the difference in meaning of "POTENTIAL" and "VOLTAGE"?
5. Arrange these voltages in sequence from the highest positive to the maximum negative: —15v., +65v., Ov., —2v., +13v., —75v.
6. Why must you always use a reference point when you describe the potential at a point in a circuit?

7. The grid of a vacuum tube is at GROUND potential. The cathode is positive with respect to the ground. What is the potential of the grid with respect to the cathode?
8. Current flows through a resistor from LEFT to RIGHT. Which end of the resistor is POSITIVE?
9. A sine-wave current is flowing through a resistor. Maximum POSITIVE current is 10 amps. Maximum NEGATIVE current is —8 amps. (*a*) Is there a d-c component? (*b*) Why or why not?
10. (*a*) Two currents are "in phase." What does this mean? (*b*) Two currents are "90° out of phase." What does this mean?

CHAPTER 3

RESISTANCE

1. A 3-cell, 6-volt storage battery with a total internal resistance of 0.03 ohm is connected to a motor with a resistance of 0.02 ohm. (*a*) What is the IR drop developed by the current across the motor? (*b*) Across the battery?
2. Replace the motor in question 1 with a lamp which has 100 ohms resistance. (*a*) What IR drop is developed across the lamp? (*b*) Across the battery?
3. You wish to develop maximum VOLTAGE across an external resistance. What ratio of external-to-internal resistance should you use?
4. You wish to develop maximum POWER in an external circuit. what ratio of external-to-internal resistance should you use?
5. You are going to use a transformer to match a 20-Ω circuit to a 500-Ω line. What turns-ratio must the transformer have?
6. What makes up EFFECTIVE RESISTANCE?
7. (*a*) What is SKIN EFFECT? (*b*) How can you reduce skin effect?

CHAPTER 4

RESISTANCES IN RADIO CIRCUIT

1. What three types of resistors are used most in radio circuits?
2. You are given three radial-type resistors. The color code of each is given here. What is the resistance of each?

	a	*b*	*c*
Body	Black	Violet	Brown
End	Green	Green	Brown
Dot	Brown	Yellow	Brown

3. What information do the following color schemes give you about these two axial resistors?

Spot	*a*	*b*
1	Brown	Violet
2	Orange	Green
3	Green	Black
x	Red	Black
z	Gold	Silver

4. Where is the resistance of a wire-wound resistor usually indicated?
5. You must select a bleeder resistor that will deliver (*a*) 300 volts at 5 Ma., (*b*) 200 volts at 2 Ma., and (*c*) 100 volts at 3 Ma. The bleeder current is 5 Ma. What value must each bleeder resistance have?
6. (*a*) A variable resistor connected IN SERIES with the load and power supply is a (ohmostat) (rheostat) (potentiometer) (varisistor). (*b*) If the variable resistor is connected IN SERIES with the power supply, but PARALLEL to the load, it is a vari-sistor) (potentiometer) (rheostat) (ohmestat).
7. Draw two simple circuits showing how you would connect a variable resistor to serve as a potentiometer.

CHAPTER 5

INDUCTION

1. An inductance stores up energy in the form of (electrostatic field) (electronic particles) (electromagnetic field) (super-ionic magnetism).
2. (*a*) The current induced by an inductance WITHIN its own windings is ____?____ induction.
   (*b*) The induction that takes place *between* the windings of two separate neighboring coils is ____?____ induction.
3. State Lenz's Law.
4. Four factors determine the inductance of a coil. What are they?

CHAPTER 6

INDUCTIVE REACTANCE

1. Reactance of a coil is determined by two factors—inductance and ____?____.
2. What is the reactance of a 5-henry coil: (*a*) To a frequency of 100 cycles? (*b*) To a frequency of 1,000,000 cycles.

3. (Reactance) (Impedance) is the opposition by the inductance only to the flow of a.c., while (reactance) (impedance) is the opposition by the inductance AND the d-c resistance to the flow of a.c.
4. If you were able to have a pure reactive circuit, what would be the phase relationship between the current and the voltage?
5. Find the impedance of a circuit that contains 40 ohms resistance and that contains a coil with a reactance of 30 ohms.
6. What current will flow if you connect the circuit of Question 5 to a 110-volt generator?

CHAPTER 7

INDUCTANCES USED IN RADIO

1. Match-up the most suitable part with the proper circuit in the following list__

Part		*Circuit*
1. A-F choke	______	Tuning stages of receiver
2. R-F choke	______	Between the r-f amplifiers and power supply
3. A-F transformer	______	Power supply fillers
4. R-F transformer	______	Coupling two audio amplifiers

2. An inductance for an A-F circuit has an (iron) (air) core and a (high) (low) L, while the inductance for an R-F circuit has an (iron) (air) core and a (high) (low) L.
3. (*a*) Where will you find a LUMPED inductance? (*b*) A DISTRIBUTED inductance?
4. (*a*) One primary terminal of a transformer reaches maximum current value at the same instant that one secondary terminal of the transformer reaches maximum current value. This is called (polar coincidence) (transformer polarity) (terminal polemics) (phase transincidence).
   (*b*) On a transformer, what is designated by the letter X? By the letter H?
5. To connect the primaries of two transformers IN SERIES, you'll connect (an X terminal to an H terminal) (an X_1 to an X_2) an H_1 to an H_2).
6. How would you determine the polarity of an unmarked transformer?
7. You want to connect three single-phase transformers to form a three-phase, STAR-STAR circuit. Draw the circuit diagram, and indicate polarities.
8. You want to connect three single-phase transformers to form a three-phase, DELTA-STAR circuit. Draw the circuit diagram, and indicate polarities.

CHAPTER 8

THE CONDENSER

1. (*a*) How do electrons charge a condenser? (*b*) How does a.c. get through a condenser?
2. In a pure condenser-circuit, current (lags voltage by 90°) (leads voltage by 90°) (is in phase with voltage) (leads voltage by 180°) (lags voltage by 180°).
3. (*a*) What is the reactance of a 1-mf. condenser to a frequency of 100 cycles? (*b*) To a frequency of 1,000,000 cycles?
4. In a condenser circuit, (the higher the frequency, the lower is the reactance) (the higher the frequency, the higher is the reactance) (the lower the frequency, the higher is the reactance) (there is no relationship between frequency and reactance).
5. What relationship of frequency to reactance makes the condenser a good filter for separating high-frequency and low-frequency currents?
6. A capacitive circuit has a reactance of 60 ohms and a resistance of 80 ohms. (*a*) What is the impedance of the circuit? (*b*) Does the phase angle LEAD or LAG?

CHAPTER 9

RADIO CONDENSERS

1. (*a*) In a radio circuit, you'll find large variable condensers in the (tuned a-f) (tuned r-f) (amplifier) stages. (*b*) Where will you find trimmer condensers in a radio?
2. On what type of condensers must you be careful to check polarities? Why?
3. The WORKING VOLTAGE of a condenser is (the average voltage through it) (the highest operating voltage the condenser can safely be applied without burning) (the voltage at which the condenser works best) (the voltage at which the condenser has maximum reactance).
4. You (can) (cannot) use electrolytic condensers to conduct a.c.
5. You use a shorting bar on large electrolytic condensers to (reduce the clearance between condenser plates) (to realine the condenser plates) (to avoid getting knocked on your fantail by the charge that may be on the condenser) (to shorten the electronic length of the plates).
6. (*a*) Where will you find lumped capacities? (*b*) Distributed capacities?
7. A mica condenser has the color code GREEN, RED, BROWN. What's its capacity?

8. What does a daub of GOLD paint on a mica condenser mean?
9. A paper condenser has a BLUE band around one end. What does that mean?
10. A mica condenser carries this color code—YELLOW, RED, YELLOW, BROWN, SILVER, GREEN. What do you know about the condenser?

CHAPTER 10

THE TIME CONSTANT

1. What is an R-C circuit?
2. At what instant does a condenser have maximum rate of charge?
3. A TIME CONSTANT is the length of time it takes a condenser to absorb (38.5%) (82.5%) (62.5%) (68.5%) of the applied voltage.
4. A condenser is fully charged when the voltage across the condenser is (87.5%) (62.5%) (98.6%) (100%) of the applied voltage.
5. It takes (one) (six) (10.33) (36) time constants to give a condenser a practically full charge.
6. Figure the time constants in seconds and in microseconds for the following combinations of resistors and condensers—

	R	C
(*a*)	10,000Ω	0.02 mf.
(*b*)	2,000,000Ω	0.005 mf.
(*c*)	1½MΩ	1.000 mf.

7. A potential of 200 volts is applied to a condenser. How much voltage does it absorb during (*a*) the first time constant, (*b*) the second time constant, (*c*) the third time constant?
8. An 0.5 mf. condenser is connected in series with a 100,000 ohm resistance to a 100 volt power supply. (*a*) What is the voltage across the condenser at the end of 0.05 second? (*b*) At the end of 0.15 second?
9. One most satisfactory electronic timing device you could devise would consist of an (L-C) (R-C) (2-C) (C-F) circuit.
10. What value of resistance would you use with an 0.04 mf. condenser to produce a time constant of 0.08 second?

CHAPTER 11

RESONANCE

1. In an L-C circuit at resonance, X_C is (twice) (half) (equal to) (1.732 times) X_L.

2. The electrical characteristics of a SERIES L-C circuit at resonance are (impedance maximum, current maximum) (impedance maximum, current minimum) (impedance equal to current) (impedance minimum, current maximum).
3. What are the electrical characteristics of a PARALLEL L-C circuit at resonance?
4. What makes up a tank circuit?
5. How can you raise the resonant frequency of an L-C circuit?
6. What is the "Q" of a coil?
7. If you want a parallel L-C circuit to tune sharp, you'll use a coil with a (high) (low) (mid-point) "Q."

CHAPTER 12

FILTERS

1. (*a*) Draw a circuit diagram for a LOW–PASS filter. (*b*) For a HIGH–PASS filter.
2. (*a*) In a high-pass filter, you place the inductance between the (input and the condenser) (resistance and condenser) (input and ground) (trimmer and reactance). (*b*) Why?
3. Draw circuit diagrams for (*a*) An L-section band-pass filter, and (*b*) A–T-section band-pass filter.
4. In a band-suppressor filter circuit, where would you put the parallel L-C circuit?
5. (*a*) The PLATE tank circuit of a receiver is a (series) (parallel) (series-parallel) (series-series) L-C circuit.
   (*b*) The GRID tank circuit of a receiver is a (series) (parallel) (series-parallel) (series-series) L-C circuit.

CHAPTER 13

SCHEMATIC DIAGRAMS

1. Ask the chief to let you see the schematic diagrams for the various transmitters and receivers on your ship. Test your ability to read the diagrams and locate the parts in the equipment. Ask the chief or an ETM to check you on this.
2. Viewed from the bottom, the contacts of an octal tube socket are numbered (clockwise) (counterclockwise) from the (grid prong) (heater prong) (key slot) (cathode prong).
3. (*a*) Match-up the part name with the correct color of each lead for a POWER TRANSFORMER—

1. Red	______	Filament Winding
2. Yellow	______	High-voltage Plate Winding
3. Green	______	Rectifier Filament Center-tap

4. Yellow-blue striped ______ Rectifier Filament Winding

(*b*) Match-up the part name with the correct color of each lead for an I–F TRANSFORMER—

1. Blue ______ "B+" lead
2. Red ______ grid return
3. Green ______ grid lead
4. Black ______ plate lead

CHAPTER 14

THE DIODE

1. In a diode, the electrons travel from the ____?____ to the ____?____.
2. In a direct-heater tube, the filament also serves as the (anode) (pentagrid) (cathode) (node).
3. (*a*) The space charge is formed from (molecules) (ions) (electrons) (atoms) (protons). (*b*) It is formed around the (anode) (pentagrid) (cathode) (node) by the ____?____ which shoot (into) (out of) (toward) (away from) the ____?____.
4. Electrons flow only from the cathode to the (positive) (negative) plate because the electrons are (positive) (negative).
5. (*a*) The emitter for transmitter tubes is usually (thoriated tungsten) (tungsten) (barium oxide). (*b*) Why?
6. If you increase the positive potential on the plate of a diode, what happens to the current flow through the tube?
7. You've increased the diode plate potential to a point where no greater number of electrons can flow across the tube, even if you increase plate potential further. What point have you reached?
8. What does a rectifier do?
9. Why can a diode be used to convert a.c. to d.c.?

CHAPTER 15

POWER SUPPLIES

1. (*a*) Name the three parts of a typical power supply.
   (*b*) What does each part do?
2. If your rectifier passed only half of the a-c sine voltage applied to it, you have a ____?____ rectifier.
3. Draw a circuit diagram for the rectifier in question 2.
4. Describe how a filter smooths out the d-c ripple from rectified a.c.

5. If rectification takes place on both halves of the a-c cycle, you have a ____ ? ____ rectifier.
6. Draw a circuit diagram for the rectifier in question 5.
7. What is the important difference between a diode to be used in a half-wave rectifier and a diode to be used in a full-wave rectifier?
8. If rectified a.c. flows EVERY OTHER 180° of the cycle, you are using a ____?____ rectifier. If it flows EVERY 180° of the cycle, you are using a ____?____ rectifier.
9. What two advantages does a full-wave rectifier have over a half-wave rectifier?
10. What is the ripple frequency of a 60-cycle line current after it passes through: (*a*) A half-wave rectifier, (*b*) A full-wave rectifier?
11. Draw a schematic diagram for a choke input filter.
12. (*a*) You want maximum current output from a transformer. Would you use a condenser input filter or a choke input filter?
    (*b*) You want maximum output voltage from a transformer. Would you use a condenser input filter or a choke input filter?
13. You'll usually find choke input filters used with (transmitters) (receivers).
14. What is "safe inverse peak voltage"?
15. (*a*) In selecting a condenser to be used in a filter circuit, your choice is governed mainly by the (resistance of the filter) (frequency of current) (working voltage) (inductance of the coil).
    (*b*) In selecting a choke for a filter circuit, your choice is governed mainly by the (resistance of the coil) (total current-carrying capacity of the choke) (voltage through the choke) (reactance of the choke).
16. A swing choke offers (high) (low) reactance to high current, and (high) (low) reactance to low current.
17. At no-load, the voltage is 120 volts. At full-load, the voltage is 112 volts. What is the regulation of the power supply? This is (good) (poor) regulation.

CHAPTER 16

MORE POWER SUPPLIES

1. Draw the circuit for a three phase rectifier power supply.
2. Three-phase rectified direct current is smoother because the voltage (never falls below 77% of peak value) (is in phase three times every 180°) (never falls below 50% of peak value) (has a peak value 70% greater than average value).

3. Draw a circuit diagram for a bridge rectifier. Be sure to include current direction arrows.
4. What is the advantage of connecting rectifier tubes in parallel?
5. (*a*) Draw a circuit diagram of the CHARGING circuit of a voltage doubler.
   (*b*) Of the DISCHARGING circuit.
6. In a voltage-doubler rectifier, each condenser is charged in turn to (70.7% of peak voltage) (62.5% of peak voltage) (100% of peak voltage) (1.732 times peak voltage). The two condensers are connected in (series) (parallel).
7. Voltage doublers are used with loads requiring (large) (small) amounts of current.
8. How does the mercury in a mercury vapor tube improve the conductivity of electrons from cathode to plate?
9. List the four most important precautions to take when using a mercury-vapor tube.

CHAPTER 17

OSCILLOSCOPES

1. What five parts make up the electron gun of a cathode-ray tube?
2. The grid of a cathode-ray tube (focuses) (regulates the flow of) the electron beam.
3. How is the electron beam focused?
4. (*a*) The second anode is at (positive) (negative) (ground) potential.
   (*b*) The grid is at the most (positive) (negative) potential.
5. When you change the tube focus control, you change the potential on the (grid) (first anode) (second anode) (plate) cathode).
6. When you change the tube intensity control, you change the potential on the (grid) (first anode) (second anode) (plate) cathode).
7. Which elements of the tube carry the positioning voltage?
8. The horizontal deflection plates make the electron beam move (across) (up and down) the screen, while the vertical deflection plates move the beam (across) (up and down) the screen.
9. A cathode-ray oscilloscope generally contains (two) (three) (four) amplifiers. Name them.
10. What is the shape of voltage wave generated by the sweep generator? On which set of deflection plates is this voltage placed?
11. You generate a sine wave on the tube screen by applying a (sinusoidal) (santooth) (cosinal) (cynoidal) voltage to the

vertical deflection plates, and a ___?___ voltage to the horizontal plates.

12. What use do you make of the synchronous control on an oscilloscope?
13. What two circuits of the oscilloscope are connected together by the synchronous control?

CHAPTER 18

REMOTE CONTROL SYSTEMS

1. In a typical remote control system for a communications circuit, you'll find eight pieces of equipment. What are they?
2. What purpose does the transfer panel serve?
3. (*a*) A cable is marked MHFA-7. What does this mean?
   (*b*) A cable is marked TTHFA-2. What does this mean?
4. A shading pole is used with (a.c.) (d.c.) to prevent (hysteresis) (chattering) (multiple reactance) (magnetic lag).
5. (*a*) What is a keying relay? (*b*) What is its advantage?
6. Which relay breaks the circuit when the current goes too high?
7. The time-tractor and gear train relays are two examples of (high-speed) (blow-out) (deferred-action) (super-arc) relays.
8. You have a mercury-vapor rectifier on which you want to install a relay so that the filaments will be heated before the high voltage is turned into the tube. What type of relay would be best (high-speed) (blow-out) (time-tractor) (super-arc)?
9. What two types of relay contact systems are used to avoid excessive arcing at the points?

ANSWERS TO QUIZ

CHAPTER 1

INTRODUCTION TO RADIO

1. Electromagnetic.
2. High-frequency alternating current.
3. To radiate electromagnetic energy.
4. Receive, select, amplify, detect, and reproduce.
5. (*a*) An imaginary substance.
   (*b*) Conducts radio waves.
6. ARE the same as radio waves.
7. 164,000 nautical miles per second.
8. (*a*) 10,000 cycles.
   (*b*) 15,400,000 cycles.
9. 20-20,000 cycles per second.
10. 550-1,600 kilocycles.

CHAPTER 2

CURRENT AND VOLTAGE

1. A drift or flow of electrons toward the positive pole.
2. Positive objects repel positive objects, while positive objects attract negative objects.
3. Ionized.
4. POTENTIAL indicates the ability to do work. VOLTAGE indicates the DIFFERENCE in potential—the difference in ability to do work.
5. +65v., +13v., Ov., —2v., —15v., —75v.
6. No point is ever at ZERO potential. An object is positive only because some other object is LESS positive.
7. Negative.
8. The right end.
9. (*a*) Yes.
   (*b*) Because more current, 2 amps, is flowing in the positive direction than in the negative direction.
10. (*a*) The two currents reach their maximum values at the same instant.
    (*b*) One current becomes maximum 90° later in rotation than the other current.

CHAPTER 3

RESISTANCE

1. (*a*) 2.4 volts.
   (*b*) 3.6 volts.
2. (*a*) 5.99 volts
   (*b*) 0.01 volt.
3. External resistance at least TEN TIMES the internal resistance.
4. One-to-one. External resistance equal to internal resistance.
5. Five-to one.
6. All the resistances that tend to reduce current flow in an a-c circuit.
7. (*a*) The tendency of high-frequency currents to skate over the surface of the conductor.
   (*b*) Use a hollow-tube conductor instead of a solid wire.

CHAPTER 4

RESISTANCES IN RADIO CIRCUIT

1. Carbon, variable, and wire-wound fized condensers.
2. (*a*) 50Ω.
   (*b*) 750,000Ω.
   (*c*) 110Ω.
3. (*a*) 13,500Ω, 5% tolerance.
   (*b*) 750Ω, 10% tolerance.
4. On a metal tag attached to the resistor.
5. (*a*) 10,000Ω.
   (*b*) 12,500Ω.
   (*c*) 20,000Ω.
6. (*a*) Rheostat.
   (*b*) Potentiometer.
7. Check your circuits with figure 36, page 46.

CHAPTER 5

INDUCTION

1. Electromagnetic field.
2. (*a*) Self-induction.
   (*b*) Mutual induction.
3. Lenz's law—the induced voltage tends to oppose any change in the circuit conditions.
4. Diameter of the coil, length of coil, radial depth of a coil, and number of turns on coil.

CHAPTER 6

INDUCTIVE REACTANCE

1. Frequency.
2. (*a*) 3,140Ω.
   (*b*) 31,400,000Ω.
3. Reactance, impedance.
4. Current LAGS voltage by 90°.
5. 50 ohms.
6. 2.2 amps.

CHAPTER 7

INDUCTANCES USED IN RADIO

1. (*a*) A-f choke used with power-supply filters.
   (*b*) R-f choke used between the r-f amplifier and the power supply.
   (*c*) A-f transformer used to couple two audio amplifiers.
   (*d*) A-f transformer in tuning stages of receiver.
2. An inductance for an a-f circuit has an iron core and a high L, while the inductance for an r-f circuit has an air core and a low L.
3. (*a*) In a transformer or choke coil.
   (*b*) As stray inductance between parallel lead wires of an amplifier.
4. (*a*) Transformer polarity.
   (*b*) X marks the LOW-voltage side of the transformer, H marks the HIGH-voltage side.
5. An X_1 terminal to an X_2 terminal.
6. Connect a primary lead to a secondary lead. Next, connect the primary leads to an a-c supply. Connect a voltmeter across the primary and secondary leads that are not connected together. If the voltmeter reads, the SUM of the primary and secondary voltage, the terminals are of OPPOSITE polarity.
7. Check your diagram with figure 59, page 72.
8. Your diagram should look like figure 62, page 75.

CHAPTER 8

THE CONDENSER

1. (*a*) They enter one plate of the condenser and leave the other plate.
   (*b*) As the a.c. reverses its direction, electrons surge in and out of the condenser plates.

2. Current LEADS voltage by 90°.
3. (*a*) About 1,578 ohms reactance.
   (*b*) About 0.16 ohm reactance.
4. The higher the frequency the lower is the reactance.
5. At low frequency, condenser reactance is high; at high frequency, reactance is low.
6. (*a*) 100 ohms.
   (*b*) Lead.

CHAPTER 9

RADIO CONDENSERS

1. (*a*) Tuned r-f stage.
   (*b*) In parallel with the tuning condensers.
2. Electrolytic condensers. To avoid blowing them up.
3. The highest operating voltage the condenser can safely be applied without burning.
4. You cannot use an electrolytic condenser to conduct a.c.
5. To avoid getting knocked on your fantail by the charge that may be on the condenser. In other words, SAFETY FIRST.
6. (*a*) In paper condensers, variable condensers, and electrolytic condensers.
   (*b*) Between and within leads and windings of coils.
7. 520 mmf.
8. The capacity is within 5% of the marked capacity.
9. The working voltage is 600 v.
10. The rated capacity is 4,240 mmf., with an accuracy of ± 10%, and a working voltage of 500 v.

CHAPTER 10

THE TIME CONSTANT

1. A resistor and a condenser in series.
2. At the instant the voltage is applied.
3. 62.5%.
4. 100%.
5. Six.
6. (*a*) 0.0002 second, or 200 microseconds.
   (*b*) 0.01 second, or 10,000 imcroseconds.
   (*c*) 1.5 seconds, or 1,500,000 microseconds.
7. (*a*) 125v.
   (*b*) 46.8v.
   (*c*) 17.6v.
8. (*a*) 62.5v.
   (*b*) 94.7v.

9. An R-C circuit.
10. Two megohms.

CHAPTER 11

RESONANCE

1. X_C is equal to X_L.
2. Impedance minimum, current maximum.
3. Impedance is maximum, current is minimum.
4. An inductance and a condenser in series or in parallel.
5. Decrease the value of L or C, or decrease the values of both L and C.
6. The ratio of reactance of a coil to its resistance. Or— $\frac{X_L}{R}$.
7. High "Q."

CHAPTER 12

FILTERS

1. (*a*) Check your diagram against figure 85.
   (*b*) Check your diagram against figure 86.
2. (*a*) Between the input and the ground.
   (*b*) So the inductance will offer maximum impedance to the higher frequencies.
3. Check your diagram with (*a*) Figure 87, (*b*) Figure 88.
4. In the line.
5. (*a*) Parallel.
   (*b*) Series.

CHAPTER 13

SCHEMATIC DIAGRAMS

1. No answer required.
2. Clockwise from the key slot.
3. (*a*) 1. Red = High-voltage Plate Winding. 2. Yellow = Rectifier Filament Winding. 3. Green = Filament Winding. 4. Yellow-Blue Striped = Rectifier Filament Center-tap.
   (*b*) 1. Blue = Plate lead. 2. Red = "B+" lead. 3. Green = Grid lead. 4. Black = grid return.

CHAPTER 14

THE DIODE

1. From the cathode to the plate.
2. Cathode.

3. (*a*) Electrons.
   (*b*) Formed around the cathode by the electrons which shoot out of the cathode.
4. From the cathode to the positive plate, since electrons are negative.
5. (*a*) Tungsten.
   (*b*) Because the material is rugged enough for transmitter service.
6. Tube current increases.
7. The tube saturation point.
8. Changes a two-directional current to a single-direction current.
9. Because current will flow across the diode only on the POSITIVE half-cycle of the a.c.

CHAPTER 15

POWER SUPPLIES

1. (*a*) Transformer, rectifier, filter.
   (*b*) The transformer steps the voltage up or down, the rectifier makes the current flow in only one direction and the filter smooths the pulsating d.c. into steady d.c.
2. Half-wave.
3. Check with figure 111.
4. The rapid charge and slow discharge of the filter condensers prevent the peaks of the d-c pulses from rising to maximum or falling to zero. The choke coil in the line absorbs any ripple that slips past the condensers, and the voltage across the load is practically smooth.
5. Full-wave rectifier.
6. Check with figure 115.
7. A diode for a half-wave rectifier has one plate, while a diode for a full-wave rectifier has two plates.
8. Half-wave. Full-wave.
9. Higher current capacity and less filtering required.
10. (*a*) 60 cycles.
    (*b*) 120 cycles.
11. Check with figure 118.
12. (*a*) Choke input filter.
    (*b*) Condenser input filter.
13. Transmitters.
14. The highest negative voltage that can be safely applied to the rectifier plates.
15. (*a*) Primarily by the working voltage.
    (*b*) Primarily by the current-carrying capacity.
16. Low reactance to high current, high reactance to low current.
17. Approximately 7.15%. Good regulation.

CHAPTER 16

MORE POWER SUPPLIES

1. Check with figure 124.
2. Never falls below about 50% of peak value.
3. Check with figure 128.
4. To increase the maximum available current.
5. (*a*) Check with figure 135.
   (*b*) Check with figure 136.
6. 100% of peak voltage. Series.
7. Small.
8. The ionized mercury vapor neutralizes the space around the cathode, and allows the full cathode emission to move to the plate.
9. (*a*) Never turn on the high voltage until the tube is warmed up.
   (*b*) Never overload the tube—even for an instant.
   (*c*) Always use a choke input filter.
   (*d*) Never use tube in cold climates unless an auxiliary heater is used.

CHAPTER 17

CATHODE RAY OSCILLOSCOPES

1. Filament, cathode, grid, first anode, second anode.
2. Regulates the flow of the electron beam.
3. By adjusting the relative potentials between the first and second anodes.
4. (*a*) Ground.
   (*b*) Negative.
5. First anode.
6. Grid.
7. The deflection plates.
8. Across; up and down.
9. Two. Horizontal amplifier and vertical amplifier.
10. Saw-tooth. Horizontal plates.
11. Sinusoidal.
12. To make the image stand still on the screen.
13. Vertical amplifier and sweep generator.

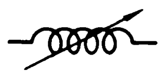
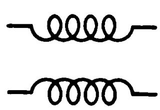
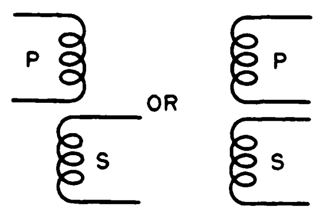
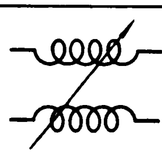
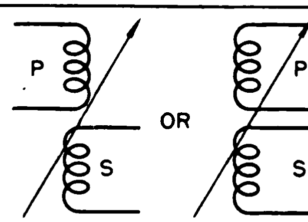
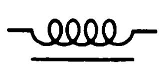
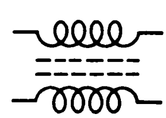
CHAPTER 18

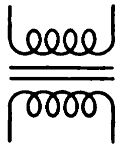
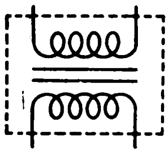
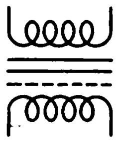
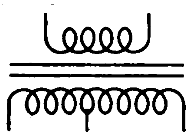
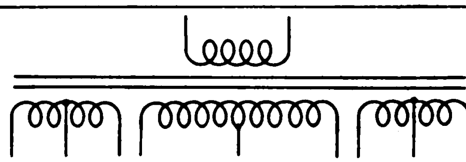
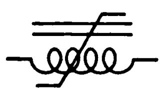
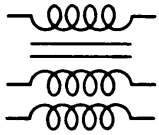
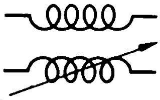
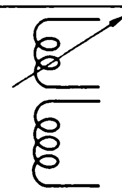
REMOTE CONTROL SYSTEMS

1. Transmitter, receiver, frequency meter, transfer panel, radiophone unit, key control panel, cables.
2. It is a switchboard on which the operator can plug-in the various transmitters and receivers.
3. (*a*) Multi, heat and flame, armored, 7-wire.
   (*b*) Telephone twisted, heat and flame, armored, 2-wire.
4. Used with a.c. to prevent chattering.
5. (*a*) A relay operated by a hand key to key the transmitter.
   (*b*) It avoids the need for leading high-voltage lines from the transmitter to the key, hence protects the operator.
6. Overload relay.
7. Deferred-action relays.
8. Time tractor.
9. (*a*) Blow-out coils, and (*b*) Snap-wipe contacts.

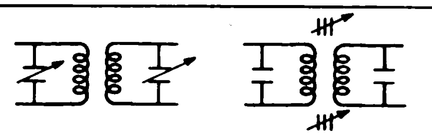
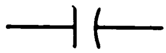
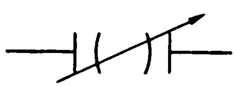
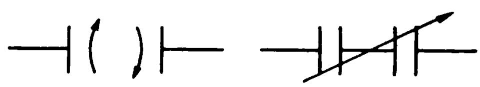
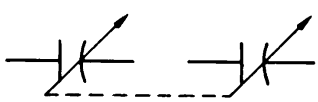
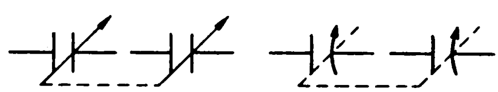
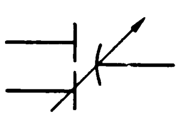
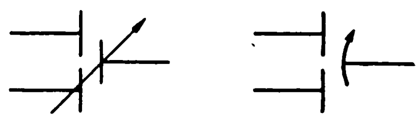
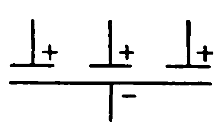
RADIO SYMBOLS

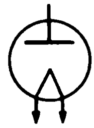
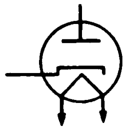
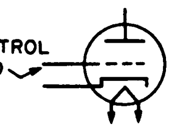
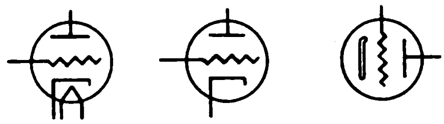
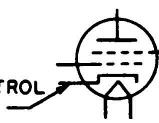
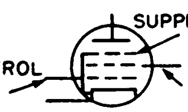
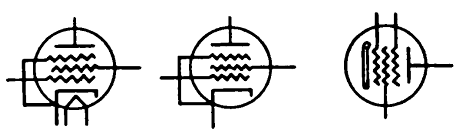
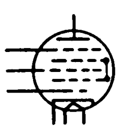
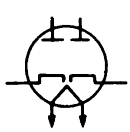
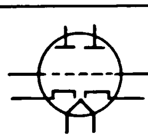
Symbols shown on the following 12 pages are standard. Navy Bureau of Ships symbols are in the left-hand column on all pages; RMA symbols are in right-hand columns.

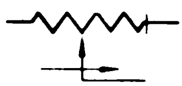
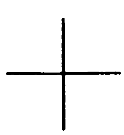
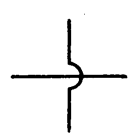
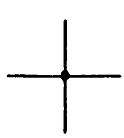
 SINGLE COIL-AIR CORE	SAME
 TAPPED COIL- AUTO TRANSFORMER	SAME
 VARIABLE OR ADJUSTABLE AIR CORE	SAME
 AIR CORE TRANSFORMER	
 VARIABLE INDUCTOR	
 CHOKE-IRON CORE-AUDIO	SAME
  MOULDED MAGNETIC CORE	 TRANSFORMER-POWDER IRON CORE (MOULDED)

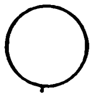
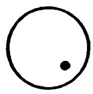
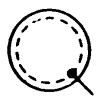
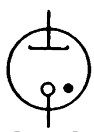
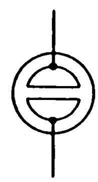
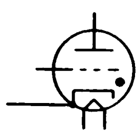
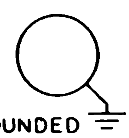
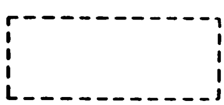
 TRANSFORMER-IRON CORE	SAME
 TRANSFORMER-SHIELDED	SAME
 TRANSFORMER WITH ELECTROSTATIC SHIELD	SAME
 CENTER TAPPED TRANSFORMER	
 SATURABLE CORE	ALSO KNOWN AS SWING CHOKE
 VARIABLE INDUCTOR-COPPER CORE	NONE
 PULSE TRANSFORMER	NONE
 VARIABLE COUPLING MOVING COIL INDICATED	

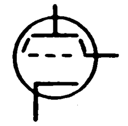
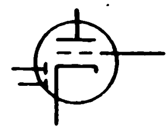
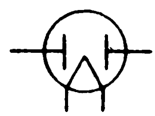
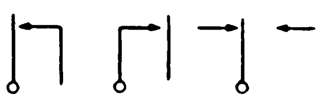
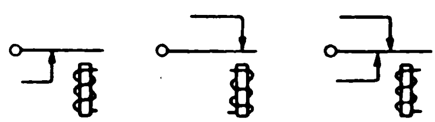
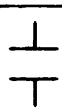
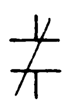
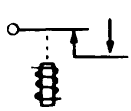
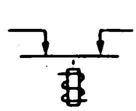
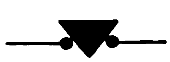
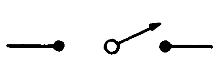
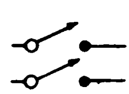
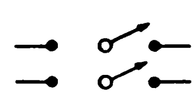
658129°—46—17

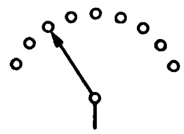
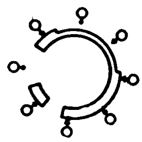
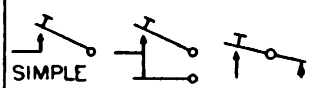
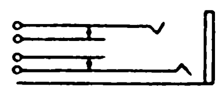
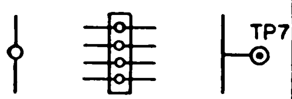
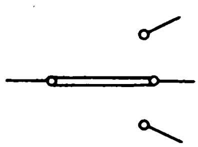
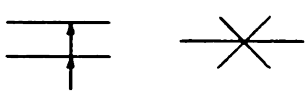
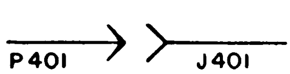
NONE	 CAPACITY TUNED INDUCTIVELY TUNED INTERMEDIATE TRANSFORMER
 CONDENSER-FIXED CURVED PLATE	
GROUNDED OR LOW POTENTIAL SIDE  VARIABLE	
 T. INDICATES TRIMMER P. INDICATES PADDER ADJUSTABLE	NONE
 VARIABLE-SPLIT STATOR	
 VARIABLE-GANG TUNED	
 VARIABLE DIFFERENTIAL	
NONE	 MULTI-SECTION, FIXED

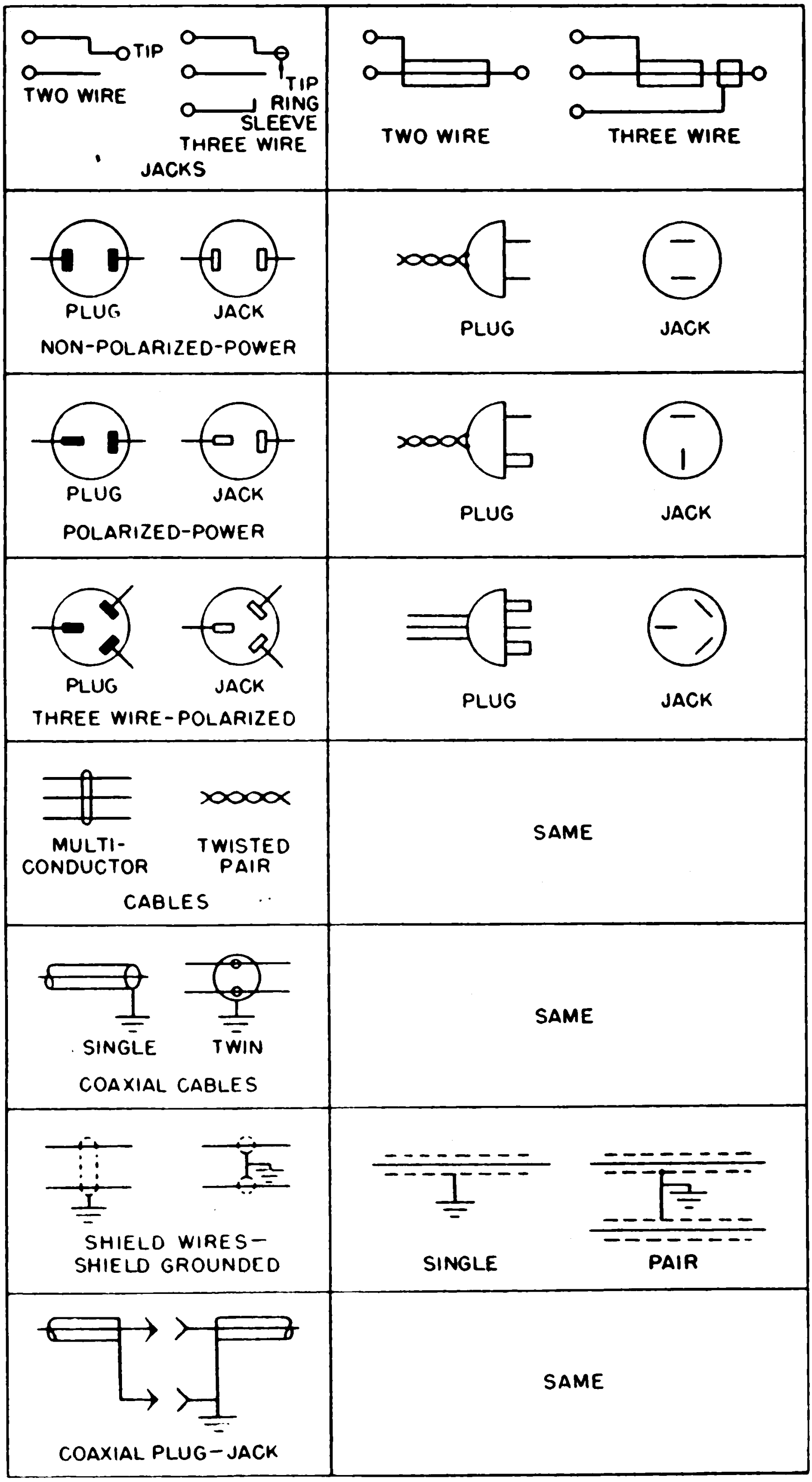
 DIODE-DIRECTLY HEATED	SAME
 DIODE-INDIRECTLY HEATED	SAME
CONTROL GRID  TRIODE-INDIRECTLY HEATED	
SCREEN GRID CONTROL GRID  TETRODE	SIMILAR TO TRIODE WITH SECOND GRID
SUPPRESSOR GRID CONTROL GRID SCREEN GRID  PENTODE - INTERNALLY CONNECTED SUPPRESSOR	 WITH EXTERNALLY CONNECTED SUPPRESSORS
 CONVERTER	SAME
 DOUBLE DIODE-INDIRECTLY HEATED	SAME
 DOUBLE TRIODE INDIRECTLY HEATED	SAME

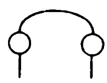
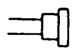
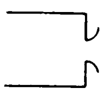
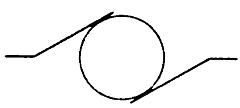
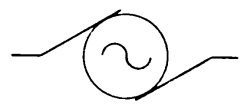
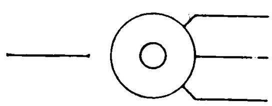
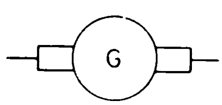
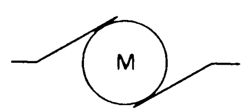
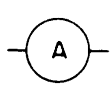
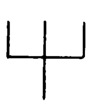
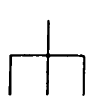
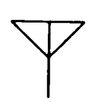
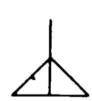
 RESISTOR - FIXED	
 VARIABLE - RHEOSTAT	
 RHEOSTAT. ARROW INDICATES CLOCKWISE ROTATION.	NONE
 POTENTIOMETER	SAME
 TAPPED RESISTOR	SAME
NONE GIVEN	 TAPPED RESISTOR-ADJUSTABLE
 WIRES CROSSING	
 CONNECTION	SAME

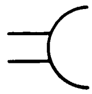
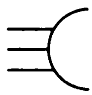
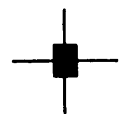
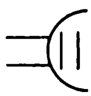
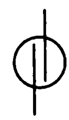
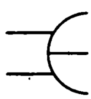
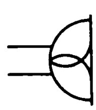
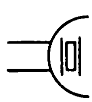
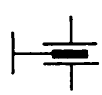
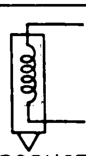
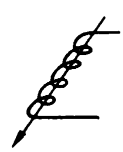
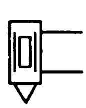
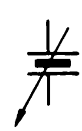
 HIGH VACUUM ENVELOPE	
 GAS FILLED ENVELOPE	
 INTERNAL SHIELD—EXTERNAL CONNECTION	
 COLD CATHODE GAS TUBE (NEON)	
 THYRATRON	SAME
 GROUNDED METAL ENVELOPE	SAME
 SHIELD	

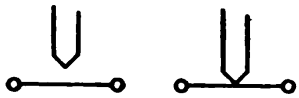
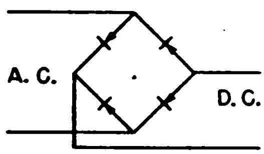
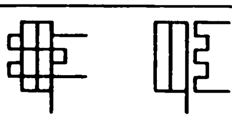
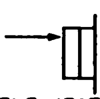
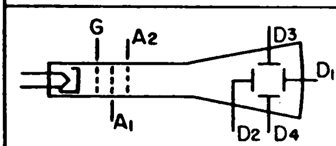
	 BEAM POWER TUBE
	 DUODIODE—TRIODE
	 DUODIODE—DIRECTLY HEATED
 MAKE — BREAK — DOUBLE THROW RELAYS	
 NORMALLY OPEN  NORMALLY CLOSED CONTACTS-DE-ENERGIZED	NONE
 SINGLE BREAK  DOUBLE BREAK BREAK CIRCUIT-MECHANICAL LINKAGE	NONE
 INTERLOCK	
 S P D T SWITCH	 S.T  D P S T  D P D T

 SELECTOR SWITCH	SAME
 WAFER SWITCH	SAME
 SIMPLE SHORTING POLE CHANGING TELEGRAPH KEYS	SAME
 TWO WIRE THREE WIRE JACKS	 TWO CIRCUIT BREAK
 TERMINAL TERMINAL STRIP TEST POINT	SAME
 STRAP CONNECTION	SAME
——MHFF 17—— WIRE TYPE  PAIR SPLICE	NONE
 PLUG – JACK	


TIP
TWO WIRE
TIP
RING
SLEEVE
THREE WIRE
JACKS
TWO WIRE
THREE WIRE
PLUG
JACK
NON-POLARIZED-POWER
PLUG
JACK
PLUG
JACK
POLARIZED-POWER
PLUG
JACK
PLUG
JACK
THREE WIRE-POLARIZED
PLUG
JACK
MULTI-CONDUCTOR
TWISTED PAIR
CABLES
SAME
SINGLE
TWIN
COAXIAL CABLES
SAME
SHIELD WIRES—SHIELD GROUNDED
SINGLE
PAIR
COAXIAL PLUG—JACK
SAME

 SPARK GAP  FUSE	SAME
 HEAD PHONES  TELEPHONE RECEIVER	SAME
 HORN GAP  CARBON BLOCKS	NONE
 ALTERNATOR- A C GENERATOR	
 THREE PHASE GENERATOR	SAME
 D C "G" GENERATOR "M" MOTOR	 D C "G" GENERATOR "M" MOTOR
 A-AMMETER MA-MILLIAMMETER G-GALVANOMETER V-VOLTMETER F-FREQUENCY W-WATT METER	SAME
 AERIAL  COUNTER POISE	 AERIAL  COUNTER POISE

 SINGLE BUTTON CARBON MICROPHONE	
 DOUBLE BUTTON CARBON MICROPHONE	
 CONDENSER MICROPHONE	
 VELOCITY MICROPHONE- RIBBON	
 MOVING COIL- DYNAMIC MICROPHONE	
 CRYSTAL MICROPHONE	
 REPRODUCER- ELECTROMAGNETIC	
 REPRODUCER-CRYSTAL	

 INDIRECTLY HEATED DIRECTLY HEATED THERMO COUPLE	NONE
 CRYSTAL DETECTOR  DRY RECTIFIER (DIRECTION OF CURRENT FLOW INDICATED)	SAME
 PIEZO CRYSTAL	SAME
 DRY RECTIFIER	SAME
 INTERNAL HEATER EXTERNAL HEATER THERMO-CUTOUT	NONE
 SELF HEATING THERMO-CUTOUT	NONE
  SCREW DRIVER CONTROL BEHIND PANEL PANEL KNOB	NONE
 ELECTROSTATIC CATHODE RAY TUBE	

QUALIFICATIONS

ELECTRONIC TECHNICIAN'S MATE 3c

(A) PRACTICAL FACTORS.

(*a*) D–5204. (General qualifications required of all petty officers.)

(*b*) EQUIPMENT ADJUSTMENTS.—Start, stop, regulate and make necessary operating adjustments on the radio transmitting, radio receiving, radio direction finder (including HFDF), sonar, radar, frequency measuring, and vacuum tube testing equipment in own ship or station, and know the safety precautions involved. This includes the shifting of frequencies within the time limit and degree of accuracy set as standard within the fleet or force to which attached. When specifically assigned, perform the adjustments listed above on Loran and Countermeasures equipment.

(*c*) CIRCUIT DIAGRAMS.—Demonstrate ability to draw and to interpret schematic circuit diagrams of simple electronic circuits.

(*d*) IDENTIFICATION OF COMPONENTS. — Demonstrate ability to locate and identify component parts of actual piece of electronic equipment by reference to the associated circuit diagram.

(*e*) TOOLS.—Demonstrate ability to handle properly and care of ordinary tools used in routine electronic service work.

(*f*) SIMPLE REPAIRS.—Demonstrate ability to make simple repairs to standard shipboard electronic equipment under qualified supervision.

(*g*) REMOTE CONTROL SYSTEMS.—Demonstrate a working knowledge of the electric and electronic remote control systems used with equipment in own ship or station.

(*h*) POWER SUPPLY SYSTEMS.—Demonstrate a working knowledge of the power supply systems used with the electronic equipment in own ship or station.

(*i*) FIRST AID.—Demonstrate a thorough knowledge of first aid with emphasis upon treatment for personnel suffering from electric shock and burns.

(B) EXAMINATION SUBJECTS.

(*a*) BATTERIES.—Have a working knowledge of the types, uses, care, and maintenance of batteries used in naval electronic equipment.

(*b*) OHM'S LAW.—Have a working knowledge of Ohm's law and be able to apply it in the solution of elementary problems.

(*c*) ELECTRONIC EQUIPMENT.—Elementary knowledge of the purpose and use of electronic equipment used in own ship or station.

(*d*) CATHODE RAY OSCILLOSCOPE.—Elementary knowledge of the theory and operation of the cathode ray oscilloscope.

(*e*) TEST EQUIPMENT.—Working knowledge of standard naval test equipment used in servicing electronic and related equipment.

(*f*) SAFETY PRECAUTIONS.—Know the safety precautions to be observed with electronic equipment in own ship or station.

(*g*) D–5203. (Fundamental knowledge required of all men in the Navy.)

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